

THE ENTRANCE OF MODERN OPTICS TO OTTOMAN SCIENCE

by

Sena Pekkendir

B.S., Physics, Boğaziçi University, 2011

Submitted to the Institute for Graduate Studies in  
Science and Engineering in partial fulfillment of  
the requirements for the degree of  
Master of Science

Graduate Program in Physics

Boğaziçi University

2015

*Dedicated to my husband Behiç and my son Ömer Melih*

## ACKNOWLEDGEMENTS

First of all, I'd like to express my sincere gratitude to my thesis advisor Prof. Levent Kurnaz for teaching me how to do academic research at first by joining me to his Soft Condensed Matter Lab when I was a sophomore. Also I'm very lucky to have been attended to his lectures on History of Science for that I discovered the branch I want to spend my life with. I'm so thankful to him to encourage and support me to write a thesis on history of science.

I'd like to express my gratitude to Prof. İhsan Fazlıoğlu for always forcing me to be better and for teaching me a great deal of wisdom of academy. I'm very grateful for the things I've learned from him and I'm lucky that I'll continue learning from him in the upcoming years.

I also would like to thank my mother Sera Sarı for being there whenever I need her and always supporting me. I'd like to thank my sister Semanur for always being a good friend and a motivation. I'd like to thank my grandfather Mehmet Ali Sarı for teaching me Ottoman and giving me his time whenever I asked for it. I'd like to thank my mother in law Ayşe Şakire for the support she gives and my father in law Prof. Mehmet Akif Aydın for the encouraging academic environment he provides in our family. I'd like to thank my eight-month old son for the meaning he brought into my life, for always being a source of joy and for standing my absence in those times I'd been working instead of being with him.

But mostly I'd like to thank my husband Behiç Aydın, for the love and attention he gives me, for our happy life together, for his endless support and encouragement.

## ABSTRACT

### THE ENTRANCE OF MODERN OPTICS TO OTTOMAN SCIENCE

In Ottoman State, modern sciences were brought into the country as a result of military targets. The first engineering schools were being established from the beginning of 18<sup>th</sup> century and foreigner scholars were brought in, to provide the transmission of knowledge. Also a comprehensive translation movement from the West was initiated. One of the pioneers of this movement, Chief Instructor of the Imperial School of Military Engineering, Ishak Efendi (d. 1836), wrote a treatise in Ottoman named *Mecmua-i Ulum-i Riyaziye* (Istanbul 1247-1250/1831-1834) using European resources. *Mecmua-i Ulum-i Riyaziye* is the first encyclopedia of positive sciences in Ottoman State and the first comprehensive study to represent positive sciences systematically. It's also credited for its presentation of Western European optical knowledge to Ottoman science properly. This study aims to examine the process of the entrance of modern optics to Ottoman State. Firstly, it presents the development of the science of optics from the ancient ages to the 18<sup>th</sup> century in order to present the back ground of the modern optical thought. Then, it focuses on the innovations in Ottoman State and the process of the entrance of modern sciences into the country. It examines the chapters of *Mecmua-i Ulum-i Riyaziye* on optics in order to track down the transmission of optical knowledge from West to Ottoman State and it examines the literature of Optical Work provided by Ottoman scholars. The study concludes in 1937, when modern concepts of optics were introduced into the country by Refik Fenmen.

## ÖZET

### MODERN OPTİK BİLİMİNİN OSMANLI BİLİMİNE GİRİŞİ

Osmanlı Devleti'nde modern bilimlerin ülkeye girişi askeri hedefler sonucu gerçekleşmiştir. 18. Yüzyılın başından itibaren ilk mühendishaneler kurulmaya başlamış ve yurtdışından hocalar getirilerek bilgi aktarımı sağlanmaya çalışılmıştır. Öte yandan, geniş kapsamlı bir çeviri hareketi başlatılmıştır. Bu çeviri hareketinin öncülerinden biri olan, Mühendishane-i Berri-i Hümayun Başhocası İshak Efendi (d. 1836), Avrupalı kaynaklardan faydalanarak Osmanlıca *Mecmua-i Ulum-i Riyaziye* (İstanbul 1247-1250/1831-1834) isimli bir eser kaleme almıştır. *Mecmua-i Ulum-i Riyaziye* Osmanlı Devleti'ndeki ilk pozitif bilimler ansiklopedisi ve de pozitif bilimleri sistematik bir şekilde sunan ilk kapsamlı çalışmadır. Bu eser, öte yandan Batı Avrupa kaynaklarındaki optik bilgileri Osmanlı Bilimine düzgün bir şekilde sunuyor olmasından ötürü itibar kazanmıştır. Bu çalışma modern optik biliminin Osmanlı Bilimine giriş sürecini incelemeyi amaçlamaktadır. Öncelikle, optik biliminin antik çağdan 18. Yüzyıla seyreden gelişimi sunularak modern optik düşüncenin arka planının sergilenmesi hedeflenmiştir. Sonra, Osmanlı Devleti'nde gerçekleşen yeniliklere ve modern bilimlerin ülkeye giriş sürecine odaklanılmaktadır. Optik bilgilerin Batı'dan Osmanlı'ya aktarım sürecinin izini sürmek için *Mecmua-i Ulum-i Riyaziye*'nin optik bilimine dair olan bölümleri ve Osmanlı Bilim İnsanlarının oluşturduğu optik literatürü incelenmektedir. Çalışma, modern optik kavramlarının Refik Fenmen tarafından ülkeye takdim edildiği 1937 yılında son bulmaktadır.

## TABLE OF CONTENTS

ACKNOWLEDGEMENTS .....	iv
ABSTRACT.....	v
ÖZET .....	vi
LIST OF FIGURES .....	x
LIST OF TABLES .....	xii
LIST OF ACRONYMS/ABBREVIATIONS.....	xiii
1. INTRODUCTION.....	1
1.1. The Emergence of the Science of Optics in Ancient Greece.....	3
1.1.1. Early History of Optics.....	3
1.1.2. Theories on Direct Vision.....	4
1.1.2.1. Intromission Theory.....	4
1.1.2.2. Extramission Theory.....	5
1.1.2.3. Mediumistic Theory.....	6
1.1.3. Geometrical Interpretation of Direct Vision.....	7
1.1.4. Geometrical Interpretation of Reflection.....	9
1.1.5. Geometrical Interpretation of Refraction .....	10
1.2. Transfer of the Science of Optics into Medieval Islam .....	11
1.2.1. The Translation Movement from Greek to Arabic.....	11
1.2.2. Theories on Direct Vision.....	12
1.2.2.1. Extramission Theory.....	13
1.2.2.2. Intromission Theory.....	16
2. ALHAZEN AND HIS SCHOOL OF OPTICS .....	20
2.1. Alhazen as the Father of Modern Optics .....	20
2.1.1. Theories on Direct Vision .....	22
2.1.1.1. The New Intromission Theory.....	22
2.1.2. Theories on Reflection .....	24
2.1.3. Theories on Refraction .....	25
2.1.4. The Influence of Alhazen in the West.....	25

2.2.	The School of Alhazen .....	27
2.2.1.	Theories on Direct Vision .....	27
2.2.2.	Theories on Reflection .....	28
2.2.3.	Theories on Refraction .....	28
2.3.	Optics in the Ottoman Science during the Classical Period .....	29
2.3.1.	Theories on Direct Vision .....	31
2.3.2.	Theories on Reflection .....	33
2.3.3.	Theories on Refraction .....	33
3.	THE DEVELOPMENT OF MODERN OPTICS .....	35
3.1.	Optics in Medieval Europe .....	35
3.1.1.	Theories on Direct Vision .....	35
3.1.2.	Theories on Reflection and Refraction.....	37
3.2.	The Development of Modern Optics.....	39
3.2.1.	Theories on Direct Vision .....	39
3.2.2.	Theories on Reflection and Refraction.....	40
3.2.3.	Theories on the Nature of Light .....	42
3.2.3.1.	The Wave Model of Light.....	43
3.2.3.2.	The Particle Model of Light.....	46
4.	THE ENTERANCE OF MODERN OPTICS TO OTTOMAN SCIENCE .....	48
4.1.	The Establishment of the Engineer Schools in Ottoman State and the Imperial School of Military Engineering.....	48
4.1.1.	Bonneval Ahmed Pasha and the First Military Regulations .....	48
4.1.2.	Baron de Tott and the First Artillery School.....	51
4.1.3.	Speed Artillery's Corps .....	52
4.1.4.	The Establishment of the Hendesehane.....	53
4.1.5.	Lafitte-Clavé and his importance in the Ottoman Reform .....	55
4.1.6.	Mühendishane-i Bahri-i Hümayun.....	57
4.1.7.	The Curriculum of Mühendishane-i Berri-i Hümayun.....	61
4.2.	Life and Works of the Chief Instructor Ishak Efendi .....	64
4.3.	Statements of Optics in Mecmua-i Ulum-i Riyaziye .....	69
4.3.1.	The First Article about Features, Formation, Reflection, Refraction of Light and Formation of Colours .....	71

4.3.2. The Second Article about the Examination of the Eye and the Formation of the Vision and also the Shape, Quantity, Distance and Motion of the Visuals in Optics .....	80
4.3.3. Third article about the conditions of reflection and deflection by flat and concave and convex mirrors .....	89
4.4. The Entrance of Modern Concepts of Optics “Photoelectricity”, “Diffraction” and “Interference” to Ottoman Turkey .....	126
4.4.1. Optical Studies after Mecmua-i Ulum-i Riyaziye in Ottoman State.....	126
4.4.2. Salih Zeki’s Treatise <i>Hikmet-i Tabiiye</i> and the Succeeding Optical Works.....	129
4.4.3. Refik Fenmen’s Treatise <i>Madde ve Ziya</i> and the Introduction of Advanced Optics to Turkey .....	134
5. CONCLUSION.....	139
REFERENCES .....	141

## LIST OF FIGURES

Figure 4.1. Formation of a visual cone. ....	73
Figure 4.2. Formation of a shadow. ....	74
Figure 4.3. Refraction of light through water surface. ....	76
Figure 4.4. Transposition of the perceived location of an image due to refraction. ....	77
Figure 4.5. Parallel transmission of light from a glass. ....	77
Figure 4.6. Focal point in a spherical glass. ....	78
Figure 4.7. Incident and reflected angles. ....	79
Figure 4.8. Separation of the white light into seven colours. ....	79
Figure 4.9. External layers of the eye. ....	80
Figure 4.10. Visual perception using a double cone of vision. ....	83
Figure 4.11. Visual perception using two triangular pyramids. ....	85
Figure 4.12. Determination of the size of an image using a two-pyramid system. ....	86
Figure 4.13. Equivalent ratios in the formation of vision. ....	87
Figure 4.14. Reflection of light on a flat mirror. ....	90
Figure 4.15. Determination of the length of an object. ....	92
Figure 4.16. Formation of vision on an inclined mirror. ....	95

Figure 4.17. Determination of the reflection points of the mirrors. ....	97
Figure 4.18. Determining the position of an image after the rotation of a flat mirror. ....	98
Figure 4.19. Formation of vision on perpendicular mirrors. ....	99
Figure 4.20. Concave spherical mirrors. ....	100
Figure 4.21. Focal point of a concave spherical mirror. ....	101
Figure 4.22. Determination of the position of the image and the focus point on a concave mirror. ....	104
Figure 4.23. Formation of vision on a concave spherical mirror. ....	107
Figure 4.24. Cylindrical mirrors. ....	108
Figure 4.25. Convex spherical mirrors. ....	109
Figure 4.26. Determination of the focus point and the position of the image in a convex spherical mirror. ....	109
Figure 4.27. Flat, concave and convex spherical mirrors on the same surface. ....	113
Figure 4.28. Formation of vision in a microscope. ....	114
Figure 4.29. A compounded microscope with two glasses. ....	116
Figure 4.30. Formation of vision in Binoculars. ....	117
Figure 4.31. Equivalent ratios in Binoculars. ....	119
Figure 4.32. Binoculars with a concave spherical mirror placed in the objective	

lens. ....	122
Figure 4.33. Position of the image on Binoculars. ....	123
Figure 4.34. Formation of vision in a solar microscope. ....	124
Figure 4.35. Formation of vision in a Camera Obscura. ....	125

## LIST OF TABLES

Table 4.1. Arabic letters versus Latin letters. .... 71

**LIST OF ACRONYMS/ABBREVIATIONS**

DOSB	Dictionary of Scientific Biography
TDVIA	Türk Diyanet Vakfı İslam Ansiklopedisi
YYOA	Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi

## 1. INTRODUCTION

For the determination of sense of information of a civilization four questions should be answered initially. What is the definition of information in that civilization? What is the identity of the person who produces this information? What are the institutions that this information was produced? Finally what is the target of this information produced in this civilization?<sup>1</sup> In the light of these questions, in order to specify the entrance of modern optics to Ottoman Science, this thesis is separated into four chapters. Firstly, the emergence and the development of the science of optics are examined beginning from the period of Ancient Greece to the transposition of these theories to Mediaeval Islam. Secondly, Alhazen who is credited to be the founder of optics and his school of optics that maintained the golden age of science in Islamic civilization are examined. The extent of this chapter included both the pre-Ottoman period and the classical period of the Ottoman state. Thirdly the development of modern optical theories from Grosseteste to Newton is researched in order to comprehend the level of optical thought in the beginning of the investigated period of this thesis which is signified to be 1733. Finally, the last chapter begins with the descriptions of the innovation movements of Ottoman State which led to the constitution of new institutions in here. These institutions provided the transference of the Western Science to Ottoman State and *Mecmua-i Ulum-i Riyaziye* which is credited to be the first encyclopedic treatise on positive sciences and one of the initiators of this transference period. The author of this treatise Chief Instructor Ishak Efendi devoted the last three articles of the third volume of the encyclopedia, to optics. The discussions of the optical information in these three articles constitute the basic subject of this thesis. The first and the second articles are summarized in chapter three; however, the third article is translated word by word from Ottoman to English. Also the figures originally used in *Mecmua-i Ulum-i Riyaziye* were cited in the thesis to represent the optical descriptions in the text visually. Chapter 4 is concluded mentioning optical works produced in Ottoman State in the period beginning with the press of *Mecmua-i Ulum-i Riyaziye* to the date 1937.

---

<sup>1</sup> İhsan Fazlıoğlu, "Bilimin Osmanlıcası", < <http://www.ihsanfazlioglu.net/yayinlar/makaleler/1.php?id=47> > (29.06.2015)

Examining former researches in history of science reveals the fact that the entrance of modern optics to Ottoman Science in the interval 1773-1937 is not investigated yet. The initial studies in the History of Turkish Optics belong to Aydın Sayılı (1913-1993)<sup>2</sup> who is also the owner of the first doctoral degree in history of science. After Aydın Sayılı, the most comprehensive studies in the History of Turkish Optics pertain to Hüseyin Gazi Topdemir.<sup>3</sup> With his works Hüseyin Gazi Topdemir gained an institutive substructure to History of Turkish Optics.

---

<sup>2</sup> See, Aydın Sayılı “A Possible Influence, in the Field of Physiological Optics of Ibn Sînâ on Ibn al Haytham”, *Belleten*, vol. XLVII, 1983, pp. 665–675. “Al-Qarafi and His Explanation of the Rainbow”, *Isis*, vol. XXXII, 1947, pp. 16–26. And “İbn-i Sînâ’da Işık, Görme ve Gökkuşağı”, *İbn-i Sînâ Doğumunun Bininci Yılı Armağanı*, 1984, pp. 203–241.

<sup>3</sup> See, Hüseyin Gazi Topdemir, “Osmanlılarda Fizik Çalışmaları”, *Osmanlı*, vol. VIII, 1999, pp. 445–460. ; “Kemâlüddîn el-Fârisî’nin Optik Çalışmaları Üzerine Bir Değerlendirme”, *Nüşa*, Issue. 6, Ankara 2002, pp. 149–168. ; *Modern Optiğin Kurucusu İbnü’l-Heysen*, Ankara, 2002.; “Mirîm Celebi’nin Gökkuşağı ve Hâlenin Oluşumu Adlı Optik Kitabı Üzerine Bir Değerlendirme”, *OTAM*, Issue. 13, Ankara, 2003, pp. 75–89.; “Optik Biliminde Bir Öncü: İbnü’l-Heysen”, *Kutadgubilig*, Issue. 3, İstanbul, 2003, pp. 107–126. ; “Aristoteles’in Doğa –Fizik- Felsefesi”, *Felsefe Dünyası*, Issue. 39, Ankara, 2004, pp. 3–19. “Kemalüddîn el-Fârisî’nin Karanlık Oda Çalışması”, *Araştırma*, vol. XIV, Ankara 1992, pp. 281–289. ; “Kamal al-Dîn al-Fârisî’s Explanation of the Rainbow”, *Bilim ve Felsefe Metinleri*, vol. I, issue. 2, Ankara 1992, pp. 103–112. ; “Işığın Niteliği ve Görme Kuramı Adlı Bir Optik Eseri Üzerine Araştırma”, Yayınlanmamış Doktora Tezi, Danışman: Sevim Tekeli, Ankara, 1994. ; “Galileo ve Modern Mekaniğin Doğuşu”, *Felsefe Dünyası*, Issue 24, Ankara, 1997, pp. 42–52. ; “Takîyüddîn’in Optiğe Katkıları”, *Bilim ve Teknik*, Issue 351, Ankara, 1997, p. 38. ; “İbn el-Heysen’in Işık Üzerine Adlı Çalışması”, *Belleten*, vol. LXI, Issue 230, Ankara, 1997, pp. 43–65. ; “Takîyüddîn’in *Kitâbu Nuri Hadakati’l-Ebsâr ve Nuri Hadi-kati’l-Enzâr* Adlı Optik Kitabı”, *Osmanlı Tarihi Araştırma ve Uygulama Merkezi Dergisi, OTAM*, vol. VII, Ankara 1997, pp. 253–286.; “Işığın Yayılımının Niteliği Konusunda Üç Önemli Adım İbn el-Heysen, Kemâlüddîn el-Fârisî, Takîyüddîn b. Marûf”, *Ankara Üni- versitesi Dil ve Tarih Coğrafya Fakültesi Dergisi*, vol. XXXVIII, Issue 1–2, 1998, pp. 381–403. ; *Takîyüddîn’in Optik Kitabı*, Ankara, 1999. ; “Kemâlüddîn el-Fârisî ve *Tenkîh el-Menâzir* Adlı Kitabı”, *A.Ü. İlahiyat Fakültesi Dergisi, Necati Öner Armağanı*, vol. XL, Ankara, 1999, pp. 433–442.

## 1.1. The Emergence of the Science of Optics in Ancient Greece

### 1.1.1. Early History of Optics

The research of optical phenomena is as early as the human history. The first written sources on optics are found in ancient Egypt. In these sources there is information about some optical illusions as the sun being seen larger during its position at the horizon than its position at the top and information about the formation of the rainbow and about some optical devices as mirrors and lenses. Construction of lenses goes to early dates in ancient Greece which is where mainly the Western optical tradition began. One example to this is the expressions in the comedy work of Aristophanes (d. 386 BC) named *The Clouds*. In which work, a transparent stone is called as a burning glass and it's stated that one can melt the glass by holding it towards the sun. Another example is Archimedes (d. 212 BC) who used mirrors to reflect the sun light and burn the approaching ships to protect a castle of his homeland. Besides these experiences of constructions of optical devices, the formation of optics began according to the examinations mainly in medicine, metaphysics and geometry.<sup>4</sup> These three fields seem to be appropriate to be stated as three bases where the optical research originated from. Medicine was concerned with the anatomy and physiology of the eye and the treatment of eye related diseases, metaphysics was concerned with the questioning of epistemology, psychology and physical causation and geometry was concerned with the geometrical explanation of the perception of space.<sup>5</sup>

Primarily, optics emerged with the name *perspectiva*<sup>6</sup> which is a field based on the examination of visual changes in objects. Hence direct vision which examines the interaction between the object and the observer is the first subject to progress in optics. Three different theories were improved about how the relation is formed between the observer and the visual item, which are the intromission theory, the extramission theory and the mediumistic theory. While the intromission theory claims that the object sends light or visual data to the eye, the extramission theory claims that the eye sends light or

---

<sup>4</sup> Hüseyin Gazi Topdemir, *Işığın Öyküsü*, Tübitak, Ankara 2007, p. 3-4

<sup>5</sup> David C. Lindberg, *Theories of Vision From Al-Kindi to Kepler*, The University of Chicago Press, Chicago 1976, p. 1.

<sup>6</sup> David C. Lindberg, "The Science of Optics", *Studies in the History of Medieval Optics*, Variorum Reprints, London 1983, p. 338.

power to the object. Furthermore, the mediumistic theory is based on the idea that the relation between the eye and the object is built by the medium between them.<sup>7</sup>

### 1.1.2. Theories on Direct Vision

1.1.2.1. Intromission Theory. The first philosophers to perform a systematic theory of light and vision in ancient Greece were the atomists. In the reports of Aetius (d. 3rd Century A.D.), it's stated that "Leucippus (d. 5<sup>th</sup> Century BC), Democritus (d. 370 BC) and Epicurus (d. 270 BC) say that perception and thought arise when images (*eidola*)<sup>8</sup> enter from outside". Additionally, in the first half of the third century Alexander of Aphrodisias mentioned that Leucippus and Democritus "attributed sight to certain images of the same shape as the object, which were continually streaming off from the objects of sight and impinging on the eye."<sup>9</sup>

The atomists attributed sight to the reception in the eye of a thin film of atoms (a *simulacrum*) departing from the surface of visible objects.<sup>10</sup> Leucippus claims that every variation that appears is a consequence of a relation and he claims that objects send an image that represents them in order to be perceived. Similarly Democritus argues that vision occurs via the occurrence of a continuous propagation from the object and the penetration of it to the eye. According to Democritus, light is a matter, consisted of small, round and fast moving atoms. Due to the light falling over the surface of the objects, the atoms composing the colors reflect from the surface. By this way, Democritus claims that the colors are originated by the varying locations of the atoms covering the surfaces of the objects.

Empedocles (d. 430 BC), another defender of the intromission theory, claims that similar to light propagating from the sun, light is able to propagate from the objects. He states that in order to transmit light, objects should be porous and light coming out of the pores of an object should be in the proper position to enter another object's pores.

---

<sup>7</sup> Topdemir 2007, p. 9.

<sup>8</sup> These thin films of atoms are stated as *eidola* in Greek, and *simulacra* in Latin. For detailed information see Lindberg, "The Science of Optics", *Studies in the History of Medieval Optics*, p. 340.

<sup>9</sup> Lindberg 1983, p. 2.

<sup>10</sup> David C. Lindberg, "The Science of Optics", *The Beginnings of Western Science*, The University of Chicago Press, Chicago 1992, p. 105.

According to Empedocles, vision also occurs by the eye being porous and by the light that is propagated from the objects outside entering from the pores of the eye. This theory being developed by the atomists and later by Empedocles, despite all the effort, wasn't accepted by other philosophers. After intromission theory, extramission theory which claims the eye as the source of light and the object as the target it reaches, gained effectiveness.<sup>11</sup>

1.1.2.2. Extramission Theory. Alcmaeon (early fifth century B.C.) is the first philosopher to express the extramission theory properly and that the theory of a visual current coming from the eye is associated with. Thophrastus mentions Alcmeon's theory of vision as "And the eye obviously has fire within, for when one is struck (this fire) flashes out".<sup>12</sup> He claims that the eye is made of fire because fire comes out during an impact to the eye. Alcmaeon also claims that the vision occurs by light that is propagated from the eye, being reflected from an object. This theory which will later be called "intraocular fire" was developed mainly by Plato.

Plato (d. 347 BC) claims that light propagates from the eye but there are two kinds of different light sources. One of the sources is the eye and the other source is the luminous object and the vision occurs by the composition of these two lights from different sources. The composed light providing the vision is called visual current by Plato. Plato's explanation of the vision by composing the light propagating from the object and the light propagating from the eye leads to the fact that his theory was a synthesis of the intromission and extramission theories.<sup>13</sup>

Plato also presents the first theory of the formation of colors by claiming they occur via the composition of light and darkness in various degrees. This theory despite being completely incorrect is important for being preparative to the color theory of Aristotle.<sup>14</sup>

Another defender of the extramission theory Galen (d. 200 BC) claims that a light intensity coming out of the eye provides perception and for this formation of perception intervention of the air is needed. Because according to Galen, the sensitization of the air by the light coming out of the eye is necessary for the occurrence of perception. This statement is intriguing for including the concept of medium.

---

<sup>11</sup> Topdemir 2007, pp. 11-13.

<sup>12</sup> Lindberg 1976, pp. 3-4.

<sup>13</sup> Topdemir 2007, pp. 13-14.

<sup>14</sup> Topdemir 2007, p. 17.

1.1.2.3. Mediumistic Theory. Aristotle (d. 322 BC) is an important figure of the ancient age to develop important considerations about the nature of light. According to him, the universe is completely occupied and the main concepts to be examined are the variations that this occupied universe is exposed to. He states that the vision is also a variation, because it arises via an interaction occurring on a sense organ.<sup>15</sup>

Aristotle stated light as the main condition for vision and he tried to analyze the nature of light. Besides other philosophers who accepted light as a component of vision, Aristotle for the first time, felt the need to examine the nature of light. By this he actualized an important initial in the history of optics. In his treatise *On the Soul*, Aristotle states light (*phos*) a variation that takes place in the transparent object and an activity of it. He stated that:

“Light is the actuality of this *quâ* transparent. But where the transparent is only potentially present, there darkness is actually. Light is a sort of color in the transparent when made transparent in actuality by the agency of fire or something resembling in the celestial body: for this body also has an attribute which is one and the same with that of fire. What the transparent is, and what the light is, has now been stated; namely that is neither fire nor body generally nor an effluence from any body, but the presence of fire or something fiery in the transparent. For it is impossible for two bodies to occupy the same space at the same time.”<sup>16</sup>

On the other hand, Aristotle claims that for the occurrence of vision a medium providing the visual object to reach the eye is necessary. Aristotle, who requires an impact on the sense organ for the vision to happen, states that this impact must be created by the medium and he states that vision occurs via the medium changing its qualification. The medium both originates light via changing its qualification and it provides the transmission of the visual object to the eye by filling the gap between the eye and the object. And the medium also takes the color of the light it transports. The effect of the mediumistic theory by Aristotle lasted until today and in modern age this theory revealed as the aether theory.<sup>17</sup>

The explanations Aristotle made with the analysis of medium are in good correlation with the arguments about aether that took place in the 19th century. According to Aristotle, the universe is completely occupied and gap is impossible because everything that exists

---

<sup>15</sup> Topdemir 2007, p. 18.

<sup>16</sup> Morris R. Cohen & I. E. Drabkin, *A Source Book in Greek Science*, Harvard 1966, p. 285.

<sup>17</sup> Topdemir 2007, pp. 21-22.

originates dependant to a matter and a form.<sup>18</sup> Aristotle's definition of light (*chroma*) is that which overlies on the surface of the object and has the power to set in motion the actually transparent.<sup>19</sup> Besides light, the duty of color in occurrence of the vision is explained by Aristotle, and hence he became the first philosopher to examine the nature of color and how it's originated.

So far Atomists, Plato, Aristotle and Galen proposed three different theories about light and the visual perception that are intromission theory, extramission theory and mediumistic theory. However none of them dealt with the mathematical extension of the visual perception in these theories.

In the meantime there were ongoing optical studies in China as well. Members of Mohism, a Chinese philosophy developed by the followers of Mozi (d. 391 BC), are the starters of optical research in China. They examined the shadow subject and understood the fact that light propagates in a straight line. They did experiments with the dark room and realized that vision of an object turns down when light transmits through a pinhole. They examined plane and concave mirrors and knew the real and virtual image concepts formed by concave mirrors. Chinese also used lenses commonly but besides the fact that Chinese knew that images of objects can be magnified or minified using lenses, they didn't tend to invent eyeglasses or telescopes.<sup>20</sup>

### 1.1.3. Geometrical Interpretation of Direct Vision

The first philosopher to approach to the subject of direct vision mathematically and to originate geometrical optics is Euclid (d. 275 BC) who is also the founder of plane geometry. Euclid handled the optical problems of vision and the propagation of light in a mathematical context and grounded on some basic principles. These principals are; that light rays come out of eye, light rays propagate linearly and propagated light originates a cone. Apart from these three principals Euclid adopted seven postulates as bases for the geometrical theorems of the *Optica*:

Let it be assumed

---

<sup>18</sup> Topdemir 2007, p. 23.

<sup>19</sup> Lindberg 1976, p. 8.

<sup>20</sup> Colin A. Ronan, *Dünya Kültürlerinde Bilimin Tarihi ve Gelişimi*, Trans: Ekmeleddin İhsanoğlu, Feza Günergun, Tubitak Press, Ankara 2003, p. 189.

- (i) That the rectilinear rays proceeding from the eye diverge indefinitely.
- (ii) That the figure contained by a set of visual rays is a cone of which the vertex is at the eye and the base at the surface of the objects seen.
- (iii) That those things are seen upon which visual rays fall and those things are not seen upon which visual rays do not fall.
- (iv) That things seen under a larger angle appear larger and those under a smaller angle appear smaller and those under equal angles appear equal.
- (v) That things seen by higher visual rays appear higher and things seen by lower visual rays appear lower.
- (vi) That, similarly, things seen by rays further to the right appear further to the right and things seen by further to the left appear further to the left.
- (vii) That things seen under more angles, are seen more clearly.<sup>21</sup>

Euclid examined mostly the problems of perspective and he didn't deal with the optical problems like qualification of the visual rays and the physiology of vision. Compared to former philosophers who presented some concepts about the nature of light and the visual perception, Euclid was concerned only with the mathematical extent of vision. On the other hand Euclid made determinations for catoptrics which examines the variation of light on mirrors and visual disabilities occurring related to this. With these determinations Euclid actualized the first theoretical expression of catoptrics. Euclid, in his explanations on catoptrics, states that light is collected on the focal point of concave mirrors and causes burning at this point. Euclid also formulated the second basic law of reflection which states that light coming to a plane mirror will be reflected with an angle equal to the incident angle. However, only formulating the law of reflection, Euclid didn't make an effort to prove it. These works of Euclid on optics was determinant in later periods and Hero and Ptolemy continued the tradition of geometrical optics which he started.<sup>22</sup>

Ptolemy (d. 150s AC) mainly known with his geocentric model in astronomy he also did some of the greatest optical works of ancient age. He developed the geometrical vision theory of Euclid as to comprise physical, physiological and psychological elements. Ptolemy, similar to Euclid, related the visual perception to the visual flux coming out of the eye, however, differing from Euclid he proposed a continuous pyramid for the visual

---

<sup>21</sup> Cohen and Drabkin, p. 258.

<sup>22</sup> Topdemir 2007, pp. 31-32.

field instead of a discrete cone. Also, contrary to Euclid who didn't state the peak point of his cone of vision, Ptolemy stated the peak of his pyramid of vision as the cornea of the eye.<sup>23</sup> In his treatise *Optics*, he defined colors as a feature of objects and the treatise also includes a research on stereoscopic view. He also proved that vision is propagated in a straight line and did some experiments to determine the size of the visual field.<sup>24</sup>

The knowledge in optics of vision reached to an important level by the works of Ptolemy. However rather than the pyramid of vision, the cone of vision is mainly accepted after him and the geometry of vision is built on this.

#### 1.1.4. Geometrical Interpretation of Reflection

Reflection which is about the variation of light on the surface of for example a mirror is a branch of optics that has been examined since early periods. Archimedes's (d. 212 BC) burning ships by focusing light on concave mirrors, experiments made in China about reflection and the geometrical explanation of reflection made by Euclid are known facts about reflection.

After Euclid, Hero continued the works on reflection and so developed the field catoptrics. Hero named his work *Catoptrica* and mentioned about spherical, plane, concave and convex mirrors. He geometrically proved that during reflection, the angle of the incident light with the mirror will be equal to the angle of the reflected light. This is the second basic law of reflection and it's stated by Euclid before without any proving. In his *Catoptrica*, Hero also divided the vision science to three parts as optics, dioptrics and catoptrics and he stated catoptrics as the most important one. Hero's proving of the law of reflection not just for plane mirrors but also for concave and convex mirrors is an important initial in catoptrics.<sup>25</sup>

The works on reflection that Hero started are continued by Ptolemy (d. 168 AD). The observations of Ptolemy on mechanics lead him to three important conclusions on optical reflection. According to Ptolemy, first of all light coming perpendicularly to the surface of a mirror turns back in the opposite direction. Secondly, light coming tangentially to the surface continues its motion without any deviation. And thirdly, light coming inclined to

---

<sup>23</sup> Topdemir 2007, pp. 32-33.

<sup>24</sup> Ronan, p. 133.

<sup>25</sup> Topdemir 2007, pp. 34-36.

the surface reflects symmetrically to the incident part. Ptolemy proved the existence of these rules by his experiments and he made determinations on how the images are formed and their varying locations with respect to an observer. According to him, objects are seen in mirrors dependant to the location of the eye and in the direction of lights reflected from the mirror through the object. And visions in the mirror appear in the direction of the normal that is sketched from the object to the surface of the mirror. Incident and reflected lights include only one reflection point and they make equal angles with the normal at that point. These consequences that Ptolemy obtained prove the law of reflection experimentally and get the law of reflection to its highest point in the ancient age.<sup>26</sup>

### 1.1.5. Geometrical Interpretation of Refraction

First examinations on refraction which is the variation on the direction of the light during transmission from one surface to another, took place in the ancient age. One of the starters of these examinations is Cleomedes (d. 1<sup>st</sup> century AC), who tried to explain the reason of sun being larger at the horizon than at the top in his treatise *On the Circular Motions of the Celestial Bodies*. Cleomedes related this image difference incorrectly to the air layer being more intense and humid at the horizon. Cleomedes also tried to explain a statement that is told before him stating that eclipse is possible during both the sun and the moon being above the horizon. He explained this statement relating it to the atmospheric refraction again. According to Cleomedes, just as the vision of a coin in an empty container becoming possible when the container is filled with water, in the atmospheric refraction the moon and the earth and the sun being in the same plane provides the vision of the sun and the moon being above the horizon with respect to an observer from the earth. This situation where eclipse is possible, named as paradoxical eclipse by Cleomedes. These observations Cleomedes remarked are very important in terms of examining the subject. However, Ptolemy is the main philosopher to theorize the optics of refraction.<sup>27</sup>

In his treatise *Optics*, Ptolemy states that visual rays may be altered in two ways. The first way is by reflection which is described as rebound of light from objects which do not permit the penetration of the visual ray. And the second way is by refraction, which is

---

<sup>26</sup> Topdemir 2007, pp. 36-37.

<sup>27</sup> Topdemir 2007, pp. 39-41.

described as the bending of light during penetration to a different density medium.<sup>28</sup> Ptolemy also states that, if light is transmitted to a more intense medium it bends towards the normal and in the opposite situation if light is transmitted to a less intense medium it bends away from the normal. Additionally, the divergence of light from the normal is dependent on the intensity difference and these statements developed the basis of Alhazen's Law of Refraction. Ptolemy determined some principles in his experiments and examinations on optical refraction. These are; light's changing its direction during transmission to a more intense or less intense medium, light's propagation as linear lines and its bending at the boundary between two different mediums with different intensities, and as a consequence of this bending light's refraction forming a quantitative angle with the normal. Apart from these principals Ptolemy tried to determine the location of the vision relating it to the case of the empty container with coin inside in which the vision becomes possible after filling the container with water. Ptolemy developed a device to examine refraction experimentally and with this device he did measurements to determine the variations of light in different mediums. The refractive device of Ptolemy is later used frequently in the experiments of refraction in Islamic world.<sup>29</sup>

## **1.2. Transfer of the Science of Optics into Medieval Islam**

### **1.2.1. The Translation Movement from Greek to Arabic**

An intensive translation movement began in Medieval Islam from Greek to Arabic and by the ninth century many of the Greek achievements in optics were translated into Arabic. By this way Greek optical traditions were reproduced in Islamic point of view. The mathematical theory of Euclid and Ptolemy, based on the idea of visual rays forming a cone of vision was developed and defended by al-Kindi (d. 873 AC). In his treatise *On Vision*, al-Kindi expressed his determinations on direct vision. This treatise, besides being effective in Islamic civilizations later became effective in Western Civilizations as well through its Latin translation. Al-Kindi's contemporary Hunain ibn Ishaq (d. 873 AC), adopted the Galenic theory of vision and presented his opinions in his *Ten Treatises on the*

---

<sup>28</sup> Cohen & Drabkin, pp. 271- 272.

<sup>29</sup> Topdemir 2007, pp. 41-43.

*Eye and Book of Questions on the Eye*. Finally in the tenth century, al-Razi (d. 925 AC) and al-Farabi (d. 950 AC) supported the theory of vision of Aristotle. The theory of Aristotle found a more comprehensive support in the eleventh century by Avicenna (d. 1037). Besides the reproduction of Greek optical traditions in Medieval Islam, the essential of the visual theories remained unchanged.<sup>30</sup>

### 1.2.2. Theories on Direct Vision

A metaphysical approach to direct vision was developed by Suhrawardi (d. 1191) who is the founder of the philosophy of Illumination. In his philosophy, he based everything on the principles of light and darkness. The primary subject of this philosophy is the nature of light and its propagation. In the philosophy of Illumination light is accepted to be the main constituent of every object, as it is described as an actuality penetrating into every object. In this context, everything but the “Pure Light” is consisted of darkness and every kind of light penetrated into objects except the pure light is accepted to be extraneous. In his explanations on the visual perception, Suhrawardi neither accepted Aristotelian theory nor the extramission theory. Arguing both of these theories he presented his own theory of vision. He stated that the whole reality was consisted of the degrees of light and darkness and only illuminated objects could have their vision. As an observer sees an illuminated object, his soul comprises it and he is illuminated by its light. According to Suhrawardi, the soul’s illumination in the presence of an object is the visual perception and the action of observing contains the illuminative character of knowledge. Hence Suhrawardi didn’t accept either the object or the observer as the source of light. His acceptance of light as the actuality and the philosophy behind it doesn’t involve scientific importance as the philosophy of Suhrawardi is a completely metaphysical approach. However, its importance lays on the process of the development of optical knowledge and its effect on growing interest on optics in the Islamic world. Suhrawardi’s philosophy of Illumination was also pioneering in the transmission of Platonic Theories to the Islamic world.<sup>31</sup>

---

<sup>30</sup> Lindberg 1983, p. 342.

<sup>31</sup> Topdemir 2007, pp. 49-51.

1.2.2.1. Extramission Theory. The first great philosopher of the Islamic world is accepted as al-Kindi, who not only contributed to the translation movement of the ninth century, but also integrated Greek philosophy with Mu'tazilite theology. Hence he contributed to the adoption of Greek philosophy in the Islamic world. One of his treatises, *De aspectibus*, is about his works on optics. This treatise is mainly a critique of Euclid's theory of vision and an attempt to complete some of the deficiency in Euclid's *Optica* and to correct it at some points.<sup>32</sup>

Euclid wrote down his seven postulates in *Optica* based on assumptions without any attempt of justification. In his first postulate, Euclid states that the rectilinear rays proceeding from the eye diverge indefinitely. Al-Kindi began his demonstration of the claim that rays are issuing from the observer's eyes with a brief summary of its four alternative forms. He stated that it was impossible for the eye to perceive sensible objects except [1] by their forms travelling to the eye or [2] by power proceeding from the eye to sensible things, by which it perceives them, or [3] by these two things occurring simultaneously, or [4] by their forms being stamped and impressed in the air and the air stamping and impressing them in the eye. While the first of these alternatives represent the intromission theory of atomists, the second theory is the extramission theory of Euclid and Ptolemy. The third alternative is the combined intromission-extramission theory of Plato and finally the fourth is the mediumistic theory of Aristotle. Al-Kindi attempted to disprove the first, third and fourth theories to show that visual perception can only be explained by Euclidean theory.<sup>33</sup>

Al-Kindi, in Propositions 1-3 of his treatise *De Aspectibus*, attempted to demonstrate rectilinear propagation of rays mentioned in Euclid's first postulate. However, he demonstrated the rectilinearity of luminous rays instead of visual rays. In his Proposition 4, al-Kindi demonstrates that the straight line bisecting any of the shadows passes through the centers of both the opaque and the luminous body. Besides Proposition 4, the Propositions 5 and 6 are also devoted to Euclid's first postulate by showing two more demonstrations of it. Euclid's third postulate in *Optica* states that those things are seen upon which visual rays fall and those things are not seen upon which visual rays do not fall. Hence, the visual process is related to visual rays originating from the observer's eye. Al-Kindi devoted his

---

<sup>32</sup> David C. Lindberg, "Al-Kindi's Critique of Euclid's Theory of Vision", *Studies in the History of Medieval Optics*, Variorum Reprints, London 1983, pp. 469-474.

<sup>33</sup> David C. Lindberg, "The Intromission-Extramission Controversy in Islamic Visual Theory: Al-Kindi versus Avicenna", *Studies in the History of Medieval Optics*, Variorum Reprints, London 1983, pp. 138-139.

Propositions 7-10 to defend this postulate. Al-Kindi, in order to defend Euclid who presented the observer's eye as the source of light, produced arguments against the intromission theory. As an example, following Theon of Alexandria (d. 405 AC), he argues that the structure of a sense organ specifies its functioning. Just like ears being hollow in order to collect the air that produces sound, eyes are spherical and mobile. So if the eyes were receivers of the rays they would have been immobile like ears. Their mobility must be providing an effect through the darkness, hence it's more sensible to accept that lights are coming out of the eye. Another argument of al-Kindi for extramission theory is that only by this the selectivity of sight can be explained. In addition, both Euclid and al-Kindi accept that rectilinear rays come out of the eye in the form of a cone. However, instead of Euclid who proposed a visual cone as a composite of discrete rays separated by spaces, al-Kindi proposed his visual cone as a continuous body of radiation. According to al-Kindi, Euclid's discontinuous visual radiation is based on the assumption that visual rays are geometrical lines having length but no width and since light has an effect on darkness and being effective pertains to three dimensional objects, visual rays must be three dimensional as well.<sup>34</sup> This determination is important regarding its effect on following Islamic philosophers as Avicenna and Alhazen later used this idea to disprove the Extramission Theory.<sup>35</sup>

Al-Kindi also indicates that radiation is emitted in all directions from every point in the surface of the cornea. Hence he disagrees with Euclid and Ptolemy who locates the apex of the visual cone within the eye. According to him the visual cone that represents the physical process of radiation must be not one but many, emerging from every point on the surface of the observer's eye.<sup>36</sup>

In his treatise *De aspectibus*, al-Kindi devotes the first fourteen propositions to the critique of Euclid's theory of vision. The remaining ten propositions are about the nature of the visual process. As in his Proposition 15, after a long discussion of the speed of propagating light rays al-Kindi states that visual rays are propagated instantaneously. In Propositions 16-18, he generates the law of equal angles for reflection of both luminous and visual rays from plane, concave and convex surfaces. In Propositions 19-21 he states the physical and geometrical features of vision through a mirror. Finally in Propositions

---

<sup>34</sup> Lindberg 1983, pp. 474-479.

<sup>35</sup> Topdemir 2007, p. 53.

<sup>36</sup> Lindberg 1983, pp. 484-485.

22-24 al-Kindi explains the effect of distance and of angle subtended by the visible object on perception. *De aspectibus* which is mainly a geometrical treatise includes some definitions and statements about the physical nature of the visual rays as well. As an example al-Kindi defines a ray as “the impression of luminous bodies in dark bodies, denoted by the name ‘light’ because of the alteration of accidents produced in the bodies receiving the impression.” And he also states that the effect of sight is “that it converts that which is opposite” in his analysis of variations in the sensitivity of the visual cone. Finally, in his discussions about reflection al-Kindi refers to the transformation of the medium provoked by sight as a “resolution”. The important part about these statements of al-Kindi is they take him outside the Euclidean tradition and relate him with the Galenic theory of vision.<sup>37</sup>

Another form of the extramission theory, the Galenic theory of vision differs from other ancient theories of vision by including anatomical and physiological details about visual perception. Hunain Ibn Ishaq the leader of the Galenic school of vision, besides his translations of Greek scientific and philosophical work to Syriac and Arabic, wrote two works on ophthalmology as well. These are *the Ten Treatises on the Eye* and *the Book of the Questions on the Eye* and these books are credited for representing the penetration of Galenic theories into Islam. According to Hunain Ibn Ishaq, the air that fills the space between the object and the observer becomes the instrument of the eye and mediates between the eye and the object. Just like Aristotle and Galen, Hunain Ibn Ishaq claims that there is no flow of substance either from the visible object to the eye or in the opposite direction but instead contact between them is established through the transparent medium. However, air can perform this mediating function under two conditions. These are that the air must be transformed by sunlight and it must be transformed by an encounter with the visual spirit issuing from the eye. Hunain Ibn Ishaq’s statements diverge from Aristotelian thought into a Galenic form with this second condition. According to him, the visual spirit is not propagated from the eye to the object but a transformation of the medium is originated by the visual spirit. Additionally, following Galen, Hunain Ibn Ishaq claims that the crystalline humor is the chief organ of sight as it is the transparent medium through which visual spirit and visual impressions must pass.<sup>38</sup>

---

<sup>37</sup> Lindberg 1983, p. 486.

<sup>38</sup> Lindberg 1976, pp. 33-41.

1.2.2.2. Intromission Theory. One of the early oppositions regarding the extramission theory came from al-Razi (d. 923/24) who has a number of works on optics including *On the Nature and Method of Seeing, On the Form of the Eye, On the Conditions of Vision and On the Reason Why the Pupils Contracts in Light and Dilates in Darkness*. In these works he states that, vision doesn't occur by the emanation of rays from the eye. Also in an extent work of his, the *Kitab el-Mansuri* or *Liber ad Almansorem* he claims that pupils contraction or dilation according to the amount of light required by the crystalline humor forms a contradiction to Hunain's claim about light rays emanating from the eye.<sup>39</sup>

Another early opposition to the Euclidean and Galenic theories came from al-Razi's contemporary al-Farabi, mentioned as the first great Islamic expositor to Aristotle. Al-Farabi states his opinions on light and vision in his treatises *Catalogue of the Sciences* and *The Model State* where he seems to present two different approaches on vision. In his *Catalogue of the Sciences* he supports the Euclidean theory of vision stating that "Everything which is observed is seen only through a ray which pierces the air." and he states that "Every transparent body going from a point where it touches our sight up to a point where it falls on the object seen." On the other hand, in his treatise *The Model State* he seems to be supporting Aristotelian view on vision claiming that;

"In the nature of the visual power that is in the eye, there is no aptitude to become vision in actuality; nor in the nature of colors an aptitude to be visible in actuality. The sun imparts to the eye a light that illuminates it, and to colors a light that illuminates them. Through the light that it receives from the sun, vision becomes seeing in actuality."

Hence in his second approach he attributes the action of vision to the external light rather than the observer's eye.<sup>40</sup>

Avicenna, who is accepted to have the strongest arguments against the extramission theory, states his views on the theory of vision in a variety of works including *The Book of Healing, The Book of Deliverance, Epistle on the Soul, Book of Knowledge* and *Canon of Medicine*. In these treatises he works a great deal to refute the alternative theories on vision besides the Aristotelian theory of vision. As an example, Avicenna divides the Euclidean theory of vision to four categories to refute each of them separately. (i) The radial corporeal substance emanating from the eye constitutes a single homogenous conical body, which is in contact with the entire visible object and also with the observer's eye. (ii) That which issues from the eye is a continuous substance, which makes contact with the entire

---

<sup>39</sup> Lindberg 1976, p. 42.

<sup>40</sup> Lindberg 1976, pp. 42-43.

visible object but loses contact with the observer's eye. (iii) The substance issuing from the eye consists of separate rays or parts, not in mutual contact. These rays thus touch only certain portions of the visible object. (iv) The radial corporeal substance does not make contact with the visible object at all. Avicenna rejects the first version of the Euclidean theory stating its nonsense as it suggests that from something as small as the eye can emerge a continuous substance large enough to fill a hemisphere of the world. Another fact is that the extension of a continuous radial body as far as the fixed stars would require the absence of the intervening air. The second and fourth version of the Euclidean theory can be rejected by the fact that, if that which issues from the eye should lose contact with the eye or fail to make contact with the visible object it doesn't serve the purpose of the extramission theory which mainly aims to establish contact between the observer and the visible object. Finally the third version of the Euclidean theory which claims that the substance issuing from the eye consists of discrete rays in contact with both the eye and the visible object, seems to be the closest version to Euclid's theory of vision. However, it can be rejected by the fact that the observer would perceive the points light touches and he wouldn't perceive the points light can't reach. Also, since light is consisted of separate rays, the observer would perceive the object only partially. All in all, Avicenna concludes demonstrating that vision can't occur through the emission of a substance emanating from the observer's eye by disproving the four versions of the Euclidean theory.<sup>41</sup>

Besides the Euclidean theory of vision Avicenna also disproved the Galenic theory of vision in order to corroborate the Aristotelian theory of vision. He disproved the Galenic theory of vision which states the air emanating from the eye uses the intervening air to perceive the visible object, by claiming that the air may become the intermediate medium in either of two senses. The air can either become a true optical medium, transmitting visual impressions to the eye, or be converted into a visual organ percipient in itself. Avicenna claims that in either case the air can't occupy a new state to provide it gain a new property in itself because a state would exist in relation to all observers whereas vision is an individual phenomenon.<sup>42</sup>

Avicenna also suggested a view of his own apart from the Aristotelian view of vision. According to him vision occurs with an external effect by the appearance of an image on eye similarly to a mirror. Here eye has the function of a mirror and Avicenna explains this

---

<sup>41</sup> Lindberg 1976, pp. 43-47.

<sup>42</sup> Lindberg 1976, p. 47.

view of vision mathematically. He claimed the reason of closer objects being seen larger and further objects being seen smaller by relating it to spherical liquid in eye. Hence, further objects will be seen by a smaller arc and their vision will fall into a smaller area in the liquid of the eye, and as a result it will be seen smaller.<sup>43</sup>

Another supporter of the Aristotelian theory of vision is Averroes (d. 1198) who is the most influential of Aristotle's medieval commentators. Averroes wrote commentaries on all of the Aristotelian works available to him. One of his commentaries *Epitome of the Parva naturalia* includes a summary of Averroes's theory of vision. In this treatise, besides the commentaries on Aristotelian theory, there are innovative views of Averroes as well. One of them is Averroes's reference to visual pneuma to explain the transmission of visual power from brain to the eye. Another example of his innovations is Averroes's statement of the common sense as located behind the retina, rather than located in the heart as Aristotle claimed. Averroes, who was also aware of the scientific views of Alhazen, controverts to the extramission theories of Euclid, Ptolemy, Galen and al-Kindi by three reasons. First of all, he states that this theory claiming the rays emanating from the eye, involves the ability of the eye to see in dark. Secondly, if the soul issues forth to perceive objects far or near all the objects should be perceived with equal quality and this is a contradiction with the reality. Thirdly, if the thing issuing forth from the eye were corporeal it would take a certain amount of time to reach the further objects. If the thing issuing forth weren't corporeal and were lightlike the soul would be absent in it because only a corporeal object would serve as the substrate for the soul. As a result the only way of explanation contains the concept of intermediate medium, which would lead to the theory of Aristotle.

Another important statement of Averroes is his identification of retina as the basic photosensitive organ of the eye rather than the crystalline humor. Hence late in the sixteen and early in the seventeen century Kepler is to be credited with only the rediscovery of this fact.<sup>44</sup>

As a result, these commentaries and criticisms of Muslim philosophers about the Greek optical theories are important contributions in the history of optics. However, none of these philosophers created a new optical system and the essential of the visual theories remained unchanged. Avicenna's contemporary Alhazen is credited to formulate the first

---

<sup>43</sup> Topdemir 2007, p. 61.

<sup>44</sup> Lindberg 1976, pp. 52-54.

comprehensive alternative to Greek optical theories.<sup>45</sup> While al-Kindi claimed that only the visual cone in the extramission theory could explain the visual perception mathematically, and Avicenna claimed that the visual cone of the extramissionists is incapable of explaining visual perception physiologically, Alhazen integrated the Euclidean and Ptolemaic visual cone to his new intromission theory of vision. So he combined the mathematical advantages of the extramission theory with the physical advantages of the intromission theory and satisfied the mathematical, physical and physiological criteria. By this way, he initiated a new optical tradition.<sup>46</sup>

---

<sup>45</sup> Lindberg 1983, p 322.

<sup>46</sup> David C. Lindberg, "The Intromission-Extramission Controversy in Islamic Visual Theory: Al-Kindi versus Avicenna", *Studies in the History of Medieval Optics*, Variorum Reprints, London 1983, pp. 153-154.

## 2. ALHAZEN AND HIS SCHOOL OF OPTICS

### 2.1. Alhazen as the Father of Modern Optics

Alhazen (d. 1040) who is considered as the father of modern optics by many scholars has been attributed to more than two hundred of treatises on physics, mathematics, optics, astronomy, cosmology, meteorology, medicine, metaphysics and theology. These treatises include commentaries and analysis on the works of ancient philosophers as Euclid's *Elements*, Ptolemy's *Almagest*, Apollonius's *Conics*, Aristotle's *Physics*, *De anima* and *Meteorologica*. Alhazen's treatises which include subjects of optics are his *Kitab al-Manazir* (translated to Latin as *De aspectibus* or *Perspectiva*), *On the Paraboloidal Burning Mirror*, *On the Spherical Burning Mirror*, *On the Burning Sphere*, *On Light*, *On the Rainbow and Halo*, *On the Nature of Shadows*, *On the Form of the Eclipse*, *On the Light of the Moon and On the Light of the Stars*, *Doubts concerning Ptolemy*, *On the Nature of Sight and the Manner in Which Sight Occurs*, *On Optics according to the Method of Ptolemy*, *On the Perfection of the Art of Medicine* (including chapters on eye related diseases) and *on the Opinions of Hippocrates and Plato*.<sup>47</sup> Among these his masterwork is his *Kitab al-manazir*, where he presented his theories and proofs on optics. *Kitab al-manazir* is consisted of seven chapters; the first three of them is about direct vision, chapter 4, 5 and 6 includes theories on reflection and finally chapter 7 is about refraction.<sup>48</sup> He also has an article on optics named *Discourse on Light* where he summarizes his main arguments about the nature of light. These are;

(i) That light in luminous objects is a main characteristic of their nature. On the other hand light observed in opaque objects is an acquired characteristic.

(ii) Every transparent object transmits light and permits the eye behind them to perceive. These objects can be divided into two groups, as the ones with full penetration of light and the ones with partial penetration of light.

---

<sup>47</sup> Lindberg 1976, pp. 60-61.

<sup>48</sup> Hüseyin Gazi Topdemir, *Modern Optiğin Kurucusu: İbnü'l-Heyssem, Hayatı, Eserleri ve Teorileri*, Atatürk Kültür Merkezi Başkanlığı Press, Ankara 2002, p. 6.

(iii) These two groups can be divided into subgroups: The objects with full penetration of light can be divided as celestial and terrestrial bodies; and the terrestrial bodies can be divided into subclasses as:

- The air.
- Light and similar liquids.
- Transparent minerals and transparent stones.

Alhazen described light as a form and the definition of this form is given in his *Discourse on Light*. It is claimed that the essential form is any property present in the substance of an object. Hence light in a luminous object is an essential form of that object. Alhazen also defined the term accidental light claiming that it is an object obtaining its illumination from outside. Alhazen defines transparency as a property of the medium claiming that it allows the transmission of light through it. He defines the opacity as a property of colored objects and he claims that a transparent object obtains opacity when its density exceeds the density of the air.<sup>49</sup> Alhazen divided light into two groups as the primary lights which are emanated from the objects that are luminous and as secondary lights that are emanated from illuminated opaque objects. These two groups of light are reflected from luminous surfaces and refracted by transparent surfaces. Hence Alhazen called the first group of lights as reflected lights and the second group of lights as refracted lights. In his experiments, Alhazen used different kinds of lights as morning lights, moon lights, and fire lights in order to determine the propagation features of them. He designed a mathematical light model that whatever the source is every light is propagated as linear lines, from every point of the luminous objects to each point ahead and he added that the entire of this forms a sphere.<sup>50</sup> This rectilinear propagation of light in the form of a sphere later became a basis of Huygen's principle.<sup>51</sup> He prepared detailed experiments in order to determine the rectilinear motion of light, the properties of shadows and the use of the lens,

---

<sup>49</sup> A. I. Sabra, *The Optics of Ibn al-Haytham. Book II, Introduction, Commentary, Glossaries, Concordance, Indices*, Warburg Institute, University of London, London 1989, pp. 21-22.

<sup>50</sup> Topdemir 2002, p. 45.

<sup>51</sup> A. I. Sabra, "Ibn Al-Haytham", **Dictionary of Scientific Biography**, Scribner Imprint, New York 1981, p. 191.

the *camera obscura*. He is credited to develop a mathematical approach to the *camera obscura* for the first time.<sup>52</sup>

On the other hand, following Galen's views on physiological optics Alhazen defines the crystalline humour as the sensitive parts of the eye. Apart from Galen, Alhazen states that the crystalline humour is where the visual perception begins and he states that the brain is where the visual perception is completed.

### 2.1.1. Theories on Direct Vision

2.1.1.1. The New Intromission Theory. The extramission theory defended by Ptolemy and Euclid was effective in Ancient Greece and it was also adopted by Muslim philosophers before Alhazen. Alhazen is credited to combine the two theories of vision. The "physicists" coming from the Aristotelian tradition claimed "that vision occurs by means of a form which proceeds from the visual object to the eye" and the "mathematicians" following mainly Euclid and Ptolemy claimed that "vision occurs by means of a radiation which is emitted from the eye to the visual object."<sup>53</sup> The proper mathematical approach to the theory of vision was actualized by Alhazen and therefore he is mentioned as the second Ptolemy. In his expressions he stated clearly that visual perception won't occur unless an external light and color approaches to the observer's eye. Alhazen, after proving that light is not emanated from the observer's eye, he organized a series of experiments to demonstrate that light is emanated from the object. The actual ground of his new intromission theory relies on the fact that the occurrence of dazzling and pain in the observer's eye when he stares to a luminous object or to light for too long. This claim of Alhazen that is stated in the first book and in the fourth section of his *Kitab al-manazir*, is proven in detail. The fact that the occurrence of pain and dazzling when the eye stares to an

---

<sup>52</sup> Seyyed Hossein Nasr, *Science and Civilization In Islam*, Islamic Texts Society Press, Cambridge 1987, p. 129.

<sup>53</sup> Saleh Beshara Omar, *Ibn al-Haytham's Optics: A Study of the Origins of Experimental Science*, Bibliotheca Islamica Press, Minneapolis 1977, p. 60.

object for too long, reveals the fact that an external effect is influential on visual perception. As a result light must be emanated from an object through the observer's eye.<sup>54</sup>

Alhazen constituted his new intromission theory based on the argument that each point of the surface of the object radiates in all directions, which is stated by Al-Kindi for the first time. Hence the object is presented to a punctiform analysis and Alhazen developed an integrated theory including the mathematical, anatomical and physical approaches of sight.<sup>55</sup> His conclusions on the physiology of sight are not different from the traditional statements as he mentioned about the glacial humor as the sensitive ocular organ. Yet he included two new elements to the Aristotelian physiology of vision. One of them is that the visual sensation is a species of pain and the other is that within the glacial humor the parts of the form must be in the same order as the parts of the visible object from which the form originated.<sup>56</sup> He states that each point of the cornea of the eye is a receiver of one vertical light that is transmitted through the glacial humor without any refraction and the entire of these unrefracted lights form a cone. The base of this cone is located in the visual field and the apex is located on eye. There is only one un-refracted vertical light that is emanated from the visual field and fell on glacial humor, and which is the one that constitutes the visual perception. Hence according to Alhazen, only vertical lights are effective in vision. In these statements the signification of each point of the cornea as a receiver of only one vertical light is especially important, as this is the best comment on vision developed before the modern approach on visual perception.

Alhazen stated some principles on the mechanism of visions, which are;

- (i) That light is emanated from each point of the luminous object to each direction ahead linearly.
- (ii) Light is a feature of the content of this kind of objects. These objects are called primary light sources and light emanated from them is called primary lights.

---

<sup>54</sup> Topdemir 2002, pp. 46-48.

<sup>55</sup> David C. Lindberg, *Theories of Vision From Al-Kindi to Kepler*, The University of Chicago Press, Chicago 1976, p. 60.

<sup>56</sup> Lindberg 1976, pp. 69-71.

(iii) Visual perception occurs by the affection of light and color that is emanated from objects.<sup>57</sup>

### 2.1.2. Theories on Reflection

Ptolemy, besides his experimental proof, couldn't give an explanation to the equality of the angles of incoming and reflected lights. Alhazen became the person to be credited for the scientific explanation to the law of reflection. Devoting the fourth, fifth, and sixth books of his *Kitab al-manazir*, he presented experimental and geometrical proofs about the reflection of luminous and illuminated lights from plane, spherical, cylindrical and conical mirror surfaces. According to Alhazen, lights are reflected with equal angles because the projectile motion of the incoming light and the resistance of the mirror are not opposite to each other. This kind of downward motion which is the motion of the incoming light to the mirror surface with a specific angle will occur under affection of two forces that one of them is vertical to mirror surface and the other is parallel to it. They remain equal as the mirror surface would not prevent the secondary light. As the motion of reflection consisted of the reverse vertical force and constant parallel force will occur on the plane of these two forces. Hence the angle between the normal and the reflected light will be equal to the angle between the normal and the incoming light. The principles underlying this proof of Alhazen are the same of the principles used to explain the reflection of mechanical motion. As a result, Alhazen considering all the laws of mechanic reflection applied the concept of the rectangle of velocities to explain the motion of light. This approach is based on the fact that every motion occurs on the same direction of the resultant forces. The rectangle of velocities being an original approach of Alhazen, is later used by Galileo and Newton to explain the projectile motion. The second achievement of Alhazen on reflection is about spherical aberration. He stated that every incoming light parallel to the axis is focused at one point in the concave mirror. So this kind of mirrors has burning properties just like convex lenses.<sup>58</sup>

---

<sup>57</sup> Topdemir 2002, pp. 50-53.

<sup>58</sup> Topdemir 2002, pp. 58-60.

### 2.1.3. Theories on Refraction

Alhazen used mechanical comparisons to explain optical refraction. He compared the reflection of light with the variance of the motion of a projected stone transmitting to a medium with different resistivity. Alhazen devoted the seventh book of his *Kitab al-manazir* to explain refraction. According to him light travels very fast in transparent objects and its velocity increases in mediums with lower density. Alhazen signified that light is bended through the normal in non-transparent mediums. As he did in explaining reflection, he explained the motion of refraction with two forces that one is vertical and the other is parallel to the surface. Alhazen stated that while the speed of the second parallel force is constant, the first vertical force will lose its velocity. Hence using the rectangle of velocities to explain refraction, Alhazen stated that the speed of light will stay constant through the normal when exchanging two different mediums. He added that if the second medium is denser than the first medium the velocity will decrease and in the opposite case it will increase.<sup>59</sup>

### 2.1.4. The Influence of Alhazen in the West

Alhazen, contrary to the general tendency of the philosophers of his age didn't deal with a wide range of subjects but instead he chose to focus on one subject and do comprehensive studies in that. While his main interest was in optics, his other researches on astronomy and mathematics were not to develop new theories in those fields but to enforce his theory of vision. However, during this process he reached to some new information in astronomy and mathematics.<sup>60</sup> For example, he discovered the "Alhazen's Problem" named by the seventeenth-century mathematicians, mainly used to find the point of reflection on the surface of a spherical mirror, convex or concave, given the two points related to the one another as eye and visible object. He drew lines from two points in a plane of a circle that are meeting at a point at the circumference and making equal angles with the normal at that point.<sup>61</sup> This is a fourth-degree equation for which Alhazen used the

---

<sup>59</sup> Topdemir 2002, pp. 65-66.

<sup>60</sup> Hüseyin Gazi Topdemir, *İbn El-Heysen ve Yeni Optik*, Lotus Press, Ankara 2008, p. 29.

<sup>61</sup> Nasr, p. 129.

intersection of a circle and a hyperbola. As a result, he showed mathematically that only one reflection point is possible and he based his proof on six propositions (lemmas) in the Book V of his *Kitab al-Manazir*.<sup>62</sup>

Alhazen's works differs from the works before him for a variety of reasons. First of all, he is the first scientist to perform an integral approach to sciences and to describe his scientific method in terms of the scientific understanding in the classical period. Besides his differentiation from his age by showing interest particularly on one subject, he also became the first scientist to use experiments as a tool of both exploration and confirmation.<sup>63</sup>

Alhazen's *Kitab al-Manazir* was translated into Latin late in the twelfth or early in the thirteenth century. This work, which is the principal work of Alhazen on optics dominated Western Optical thought until early in the seventeenth century.<sup>64</sup> The earliest known Western citation was made by Jordanus de Nemore. However, Alhazen's new optical theories influenced mainly Roger Bacon, John Pecham, Witelo and many others who wrote on optics in the 1260's and 1270's like Henry of Langenstein, Blasius of Parma, Francesco Maurolico and Giambattista della Porta. The theories of vision expressed by Bacon, Pecham and Witelo are fundamentally the same as the theories of vision of Alhazen's. In their work, the anatomy of the eye, the occurrence of vision and even the evidences and the arguments they used to explain vision is similar to Alhazen's.<sup>65</sup> Alhazen's theory of vision played a fundamental role for Kepler to base his theory of the retinal image. His scheme of incoherent radiation from point sources and his recognition of the need for a one-to-one correspondence between points on the objects and points in the eye are some of the basic principles of the Keplerian theory of vision.<sup>66</sup>

---

<sup>62</sup> A. I. Sabra, "Ibn al-Haytham's Lemmas for Solving 'Alhazen's Problem'." *Archive for History of Exact Sciences*, 26(1982), pp. 299- 324.

<sup>63</sup> Hüseyin Gazi Topdemir, *İbn El-Heysem ve Yeni Optik*, Lotus Press, Ankara 2008, p. 60.

<sup>64</sup> David C. Lindberg, "Alhazen's Theory of Vision and Its Reception in the West", *Studies in the History of Medieval Optics*, Variorum Reprints, London 1983, p. 322.

<sup>65</sup> Lindberg 1983, pp. 330-331.

<sup>66</sup> Lindberg 1976, p. 86.

## 2.2. The School of Alhazen

The most important treatise of Kamal al-Din al-Farisi (d. 1320) is his works on optics, *Tanqih al-Manazir* (Corrections in Optics). This is a comprehensive interpretation of Alhazen's *Kitab al-Manazir* and the most important source on optical works after Alhazen. The fact that Kamal al-Din al-Farisi used different phrases like "he said", "I say" and "we say" reveals the idea that he might have prepared his treatise under supervision of his teacher Qutb al-Din al-Shirazi (d. 1311). Also by these phrases he might have wanted to differentiate the statements of Qutb al-Din al-Shirazi, Alhazen and his own words. *Tanqih al-Manazir* is consisted of seven articles. The first three articles is about direct vision, the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> articles is about reflection and the 7<sup>th</sup> is about refraction. The treatise also contains subjects like the formation of rainbow, dark room, quality of light, features of shadows which are subjects included in the articles of Alhazen. One of these additional articles is his work, *The Burning Sphere*, which is an examination about the variation of light on spherical surfaces. The importance of this article is al-Farisi explained the formation of shadow correctly in this work. Al-Farisi examined the new optical theories of Alhazen critically and preserved the new optical tradition he started. In this tradition optical problems are dealt with geometrically and handled as geometrical problems. Besides, these problems are examined with their hypothetical extension. As a result the geometrical and hypothetical extensions of these problems are sported with comprehensive experiments. Besides the facts that al-Farisi mostly repeated Alhazen's optical views, he succeeded more than Alhazen in explaining some of the optical issues like the formation of rainbow.<sup>67</sup> However, the information on optics which is developed by Kamal al-Din al-Farisi was not transferred to the west, staying apart from the translation movement of the 12<sup>th</sup> century. The effect of the accumulation of knowledge of Islamic optics in the West is a continuing research subject of history of science.<sup>68</sup>

### 2.2.1. Theories on Direct Vision

---

<sup>67</sup> Hüseyin Gazi Topdemir, *Işığın Öyküsü*, TÜBİTAK, Ankara 2007, pp. 76-78.

<sup>68</sup> George Saliba, *Islamic Science and the Making of the European Renaissance*, MIT Press, Cambridge 2007.

Kemal al-Din al-Farisi, based on the optical views of Alhazen, states that visual perception would not occur unless light issues from the luminous or illuminated object. Just like Alhazen and Avicenna, Farisi divided the objects into two as luminous and illuminated objects. This division is one of the innovations that Islamic optics brought into the history of optics. Before Alhazen, arguments about light were generally about the source of light and the target of it, that some of the philosophers indicated the eye and some of them indicated the object as a source of the light. However after Alhazen the fact that the object is the source of light gained a certainty. As a result the arguments about light evolved into the arguments about the nature of light. The most significant effect of Alhazen can be seen physiological optics as the visual theory of Alhazen provided a basis to Kepler's retinal visual theory.<sup>69</sup>

### **2.2.2. Theories on Reflection**

Kemal al-Din al-Farisi devoted the 4<sup>th</sup> chapter of the 1<sup>st</sup> volume of his book to the concepts of reflection. He applied the concepts of reflection to plane, concave, convex, cylindrical concave, cylindrical convex, conical concave, conical convex surfaces. He also presented the formation of the images for each mirror with drawings of his own. In his book concepts of reflection are knowledge presented before him in the ancient age and in the Islamic world and they lack of originality. However he provided a detailed explanation and presentation in reflective optics.<sup>70</sup>

### **2.2.3. Theories on Refraction**

Kemal al-Din al-Farisi devoted the 7<sup>th</sup> article of his *Tenqih al-Manazir* to the concept of refraction which according to him is a subject of vision occurring by the reception of eye objects beyond transparent mediums. The article contains six parts. The first part is the introduction part and the second part is about the penetration of light from transparent objects as rectilinear lines and the refraction of it due to the transparency of the medium. The third part is about the nature of light refracted in transparent mediums and the forth

---

<sup>69</sup> Topdemir 2007, pp. 80-84.

<sup>70</sup> Topdemir 2007, pp. 89-91.

part is the perception of eye of the objects located behind transparent mediums. While the fifth part is about the formation of the image, the sixth part is about the features of the objects eye perceived by refraction. Finally the seventh part is about the visual impairment occurring as a result of refraction. Kemal al-Din al-Farisi followed Alhazen completely in terms of handling the optical subjects, that he like Alhazen set the experiments of refraction on two bases. One of these is refraction occurring in mediums in plain surfaces and the other is refraction occurring in mediums with curved surfaces. This second type of experiments, that is examined in optics as the burning glasses provided al-Farisi to explain the formation of rainbow correctly.<sup>71</sup> He explained the phenomenon by presenting that the glass sphere filled with water will function as the droplet of water in the atmosphere. He explained this with the study of two refractions, one in the interior of the sphere, to explain the shape of the principal arc and the secondary arc and one is to explain the reversed order of colors in each of these two arcs. He prepared a dark room experiment and was able to signify that the production and multiplicity of colors are a function of both the position of the images and their luminous intensity. As a result he stated that the colors of the arc are a function of the combination of reflection and refraction.<sup>72</sup>

### 2.3. Optics in the Ottoman Science during the Classical Period

In Ottoman State physical subjects like direct vision, reflection, motions of the objects, weight densities of the objects, the formation of rainbow and ring are studied in general. These subjects are separate disciplines as mechanics, optics, hydrostatics and perspective today however these subjects were examined as the concepts of nature or the concepts of the philosophy of nature.<sup>73</sup>

First scholar to contribute optics in Ottomans was Fathallah al-Shirwani (d. 891/1486), who was an astronomer in the rein of Fatih Sultan Mehmed II. He wrote an exegesis on *el-Tezkire fi el-hey'e* of Nasîruddîn Tûsî including optics comprehensively. He claimed that optics was prerequisite for understanding the subject Astronomy and in his treatise he firstly did the anatomical and geometrical examination of the eye. Later he

---

<sup>71</sup> Topdemir 2007, pp. 96-100.

<sup>72</sup> Roshdi Rashed, “*Geometrical Optics*”, **Encyclopedia of the History of Arabic Science**, Routledge Press, London 1996, p. 668.

<sup>73</sup> Topdemir 2007, pp. 129-130.

examined optical subjects like the theories on vision, reflection and refraction of light mainly based on the theories of Alhazen and al-Farisi.<sup>74</sup> Another treatise on optics was written by Hasan al-Dihlawi in the rein of Beyadiz II. This treatise written in Farsi language is named *On Mirrors*. Also, an extensive optical study including the formation of the rainbow and the colors belongs to Mirim Celebi.<sup>75</sup>

However, the most comprehensive optical treatise in the Ottoman State is attributed to Taqi ad-Din Muhammed ibn Ma'ruf (d. 1585) and his work on optics is named *Kitab Nūr hadaqqat al-ibsār wa-nūr haqīqat al-anzār* (Book of the Light of the Pupil of Vision and the Light of the Truth of the Sights). It is consisted of an introduction and three main chapters. The 1<sup>st</sup> chapter of the treatise is devoted to direct vision, the second part is devoted to reflection and the third part devoted to refraction. In the chapter of direct vision he examined the features of vision, the features of the propagation of light, the relation between the eye and the light, the anatomy of the eye and visual disabilities. The second chapter on reflection contains the properties of the reflected lights, the properties of reflection, the properties of the reflector object, the properties of the images occurring after reflection and visual disabilities occurring after reflection. In addition in the 3<sup>rd</sup> chapter which is on refraction the subjects as the properties of refraction, the properties of refracted lights, the properties of the images occurring after refraction, the proportions of the angles of refraction and the locations of the images are contained. He also added an additional part to the 3<sup>rd</sup> chapter where he mentions about atmospheric refraction. The subject of the formation of rainbow that is explained by Kemal al-Din al-Farisi correctly, mentioned only shortly by Taqi ad-Din.<sup>76</sup> In the introduction part of his *Kitabu Nur* he states that his main mission is to simplify the concepts and problems of the optical knowledge of his age. He again states in the introduction part that Alhazen's *Kitab al-Manazir* and Kemal al-Din al-Farisi's *Tenqih al-Manazir* are the two main sources of his treatise. Also it is understood from the introduction part of his *Kitabu Nur* that he cited from Farabi and Suhreverdi's treatises and some of the ancient age philosophers.<sup>77</sup>

---

<sup>74</sup> İhsan Fazlıoğlu, "İlm-i menâzir (Optik): Osmanlılar'da ilm-i menâzir", **TDVİA**, v. 22, İstanbul 2000, pp. 131-132.

<sup>75</sup> Topdemir 2007, pp. 129-130.

<sup>76</sup> Topdemir 1999, pp. 2-4.

<sup>77</sup> Topdemir 1999, pp. 27-29.

### 2.3.1. Theories on Direct Vision

On mirrors of Hasan Al Dihlevi is consisted of two parts as the introduction and the article. The introduction part contains optical views of direct vision. Dihlevi divided the views on optics into three, claiming that the first part is the views of Aristotle and Avicenna the second part is the view of mathematicians and the third part are the philosophers besides these two groups. This division is based on the fact that after Alhazen the treatises on optics written until the seventh century are divided into two as before and after him. Between these two the natural philosophers claimed that the vision occurs by light issuing forth from the object and the mathematicians claimed that vision occurs by light issuing forth from the eye. The article part of *On Mirrors* is devoted to mirrors and the features of the images formed in mirrors. This information is prepared according to the subjects on optics developed before him. The information presents the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> volumes Alhazen's *Kitab al-Manazir* comprehensively.<sup>78</sup>

Scientists of Ottoman State of the classical era intended to show interest in many scientific fields of the age instead of focusing to only one subject. One of these scientists with the same intention is Mirim Celebi (1525), the grandson of Ali Qushji (1474). He studied astronomy, mathematics, and physics and his treatise *Risale fi el-Hale ve Kavv Kuzah* includes optical subjects. This treatise maintains its importance for its signification of the progress of optical thought in Ottomans in Alhazen – al-Farisi line. Also it makes comparisons among physicist, mathematicians, theologians and opticians of Ottoman. In his evaluations Mirim Celebi refers Alhazen as the founder of optics. He competently categorized history of optics and separated into three main groups. These are physicists that consist of Arstoteles and his falllowers; the mathematicians, that consists of Euclides and his followers and the opticists that consist of Alhazen, al-Farisi and their falllowers.<sup>79</sup> The introduction of this treatise includes general optical knowledge and the context is prepared as the same as the classical books of optics containing subjects of direct vision reflection, refraction, colors, and the formation of rainbow. The explanations in the introduction part of *Risale fi el-Hale ve Kavv Kuzah* reveal the idea that Mirim Celebi mostly cited Alhazen and Avicenna. It is also understood that he dedicated to Beyazid II.

<sup>78</sup> Topdemir 2007, pp. 130-131.

<sup>79</sup> İhsan Fazlıoğlu, “*Mirim Celebi*”, < <http://www.ihsanfazlioglu.net/yayinlar/makaleler/1.php?id=110> > Kısaltılmış hâli için bkz.: “*Mirim Çelebi*”, T.C. Diyanet Vakfı İslâm Ansiklopedisi, c. XXX, İstanbul 2005, s. 160-161.

These two philosophers Mirim Celebi preferred to cite both failed to explain the formation of rainbow. As a result Mirim Celebi failed explaining the issue as well. Mirim Celebi devoted the first chapter of his study to direct vision and qualities of it. Mirim Celebi adopted the views of Avicenna and claimed that the perception of a visual object depends on the shape, magnitude, moving or stability of the object. Mirim Celebi, in the first chapter of his study also claims that besides the views of the extramissionists and the intramissionists, there is a 3<sup>rd</sup> school of view claiming that vision occurs by the intervene of the transparent air between the eye and the object. However he added that this 3<sup>rd</sup> view was not as effective as the dominant thoughts of the intramissionist and the extramissionist.<sup>80</sup>

In his work Taqi ad-Din accepted the fact that the source of the light is the object and visual perception occurs by the light issuing forth from the object. He organized some observations and experiments to verify this thought and presented some explanations as proofs. These are that eye feels pain after observing sunlight for too long and that eye would continue to observe the color of an object inside of it even after the observer turns away from the object. Taqi ad-Din explained the nature of light by providing details with his theoretical, experimental, and geometrical drawings. He claimed that light is not a substance but an *accident*. Light is not point apart from length and width, also it is not a line or a surface. He stated that light is accepted as a point length or a surface only in geometrical drawings when explaining an optical phenomenon. He also claims that light is transmitted from a luminous object to another object in an instant. In the text from his choice to describe the speed of light it is understood that he attributes not an infinite but a very large amount to the speed of light. To prove that light is transmitted linearly he set up a dark room with little hole on one wall of it he sent light to this room via the hole blur the air with smoke and he presented the transmission of light by locating a ruler in the direction of transmission. The most important argument of Taqi ad-Din is his statement about the propagation of light from luminous objects as linear lines but spherically. The spherical propagation of light is a theory mainly attributed to Huygens. Taqi ad-Din explained the spherical propagation of light theoretically and this differentiated him from the philosophers before him.<sup>81</sup> Taqi ad-Din followed Alhazen completely in defining primary lights, secondary lights and their comparisons. He exceeded Alhazen only in his

---

<sup>80</sup> Topdemir 2007, pp. 131-135.

<sup>81</sup> Topdemir 1999, pp. 36-46.

claim about that secondary lights are propagating spherically as well as the primary lights. Besides this, another contribution of Taqi ad-Din is his claim that colors are formed as a result of refraction and reflection of light. The correct and complete explanation of the formation of the colors is attributed to Newton as a result, Taqi ad-Din's explanations are very important for being ahead of their time.<sup>82</sup> Taqi ad-Din stated that light transmitted between the eye and the object forms a cone and he claims visual process can be presented with a geometrical model in an experimental way. The visual cone is a phenomenon known since Euclid. However Taqi ad-Din's contribution was to study it experimentally.<sup>83</sup>

### 2.3.2. Theories on Reflection

In the part where he studied reflection in his book *Kitabı Nur*, he stated that there exists two kinds of lights that one is the incident and the other is the reflected. He also presented experimentally that the reflected light also forms a cone proportional to the cone of the incident light. In his experiments besides proving the principal laws of reflection he also proved the variations of light in all kinds of situation as approaching tangential, approaching with an angle and approaching vertical. He also specified experimentally that more than one images might occur by reflection and light can be reflected many times. Taqi ad-Din examined the formation of the images separately in great amount of detail for every kind of mirror.<sup>84</sup>

### 2.3.3. Theories on Refraction

Ali Qushji (d. 1474), who intended to clarify Aristotelian physical principals from optics, revealed rather illuminationist theories. He interpreted the relation of light and colour and as Fahrud-din Razi he claimed that light was not the reason of the existence of a colour but rather it was the reason of its appearance. He presented his views on colours and in some optical topics in his treatise *Şerh el-Tecrîd*, in the comment he did to the work *el-*

---

<sup>82</sup> Topdemir 1999, pp. 54-55.

<sup>83</sup> Topdemir 1999, pp. 75-76.

<sup>84</sup> Topdemir 1999, pp. 87-92.

*Tuhfe el-şâhiyye fî ilm el-hey'e* of Qutb al-Din al-Shirazi and in *Risâle fî tahkîk el-ebşâr* which he examined some problems of optics with geometric representations.<sup>85</sup>

Mirim Celebi's significations on refractions are cited completely from Alhazen, so they lack from originality. Mirim Celebi stated refraction as a property of the medium and explained the relation between the density of the medium and the angles of refraction. He especially worked on determining the connection between the incident angles of light and the percentage of refraction. Besides the fact that Mirim Celebi's views on optics lack of originality they are important in terms of presenting the fact that the level of scientific knowledge in the 15<sup>th</sup> century Ottoman Empire was the same as its contemporaries. As Bacon, Pecham and Witelo stated their views on optics by using citations of Alhazen just like Mirim Celebi.

Taqi ad-Din explained the principles of refraction in his treatise. He stated the primary principle law of refraction by explaining that the line of refraction, the normal, and the centre of the eye will always be in the same surface which is called the surface of the image. However he did not tend to examine the second principle law of refraction which is called Snell law, as he did not try to signify the sinus function besides trigonometry knowledge.<sup>86</sup> At the end of this part, Taqi ad-Din described an optical device presenting the distant objects in detail as they are very close. Knowing the fact that Galileo's first usage of the telescope was in 1609 and the *Kitab-ı Nur* was written by Taqi ad-Din in 1574, this device described in his treatise is hardly a telescope. However, this device that is magnifying distant objects might be a sighting tube, that sighting tubes are known to being used since 1100 B.C.<sup>87</sup>

As a result, it's understood from his works in optics that Taqi ad-Din seems to comprehend the optical knowledge of his age. The fact that his approach to basic optical problems shows similarity to that of Kepler's is an evidence of this.<sup>88</sup>

---

<sup>85</sup> Fazlıođlu 2000, pp. 131-132.

<sup>86</sup> Topdemir 1999, pp. 124-125.

<sup>87</sup> Topdemir 1999, pp. 141-142.

<sup>88</sup> Topdemir 1999, p. 143.

### 3. THE DEVELOPMENT OF MODERN OPTICS

#### 3.1. Optics in Medieval Europe

##### 3.1.1. Theories on Direct Vision

Grosseteste (d. 1253) describes his opinions about the nature of light stating that the fundamental corporeal substance is light. He states that light is the first form to be created in prime matter and its propagation from an original point into a sphere, results in the occurrence of spatial dimensions and everything else. Grosseteste considered optics as the basis of other natural sciences and he defined *lux* as the instruments by which god produced the macrocosm of the universe and the instruments mediating the interaction between soul and the body in the microcosm of man. He described the concepts *lux* and *lumen* not as the simple visible light but as a fundamental power propagating from the source and multiplying. Grosseteste wrote down his treatises *Commentaria in libros posteriorum Aristotelis*, *Commentarius in viii libros physicorum Aristotelis* and four other related essays in order to give a geometrical analysis of the natural propagation of power and light.<sup>89</sup>

Albertus Magnus (d. 1280) is credited in the history of science for introducing Greek and Arab sciences into the universities of the Middle Ages. He is also one of the main contributors to the rediscovery movement of Aristotle. Being acquainted to the laws of reflection, Magnus used the term “*reflexio*” for both reflection and refraction. He contributed to the explanation of the formation of rainbow by assigning individual raindrops a role in the bow’s formation.<sup>90</sup>

Roger Bacon (d. 1294), following Grosseteste’s theory of the propagation of power states that it is necessary to verify the matter of the world by demonstrations set forth in geometrical lines and he adds that every multiplication is either according to lines or angles

---

<sup>89</sup> A. C. Crombie, “*Grosseteste, Robert*”, **Dictionary of Scientific Biography**, Charles Scribner’s Sons Press, New York 1981, v. 5, pp. 549-551.

<sup>90</sup> William A. Wallace, “*Albertus Magnus*”, **DOSB**, Charles Scribner’s Sons Press, New York 1981, v. 1, pp. 99-101.

of figures. Hence just like Grosseteste, Bacon considered the science of optics as the fundamental physical science. To develop his optical thoughts the main sources of Roger Bacon were Euclid, Ptolemy, al-Kindi, and Alhazen. He also followed Grosseteste by using lenses for magnification to help to improve the natural vision.<sup>91</sup>

Pecham (d. 1292) has two treatises on optics named *Tractatus de perspectiva* and *Perspectiva communis*. These extant works show that Pecham was influenced by Grosseteste, Bacon, Aristotle, Euclid, al-Kindi, Ptolemy and Witelo but especially Alhazen. In his *Perspectiva communis* the first book is devoted to the propagation of light and color, the anatomy and physiology of the eye, the act of visual perception, physical requirements of vision, the physiology of vision, and the errors of direct vision. And his second book was devoted to vision by reflected rays and presented a careful and sophisticated analysis of image formation by reflection. Finally his third book was devoted to the phenomena of refraction, the rainbow and the Milky Way. However the theory of direct vision is the dominant part in his *Perspectiva communis*. With the aim of compromising Aristotle, Euclid, Augustine, al-Kindi, Alhazen, Avicenna, Grosseteste and Bacon, Pecham followed Alhazen in explaining the visual perception. However, he also states that the emission of visual rays from the observer's eye is not necessary or sufficient for the explanation. He states the primary agent of vision as the ray coming to the eye from a point on the visible object. Yet following Aristotle, al-Kindi and Grosseteste, Pecham also states that visual rays exist anyway and perform the function of moderating the luminous rays from the visible object and making them commensurate with the visual power.<sup>92</sup>

Witelo (d. between 1280- 1314) has written down his optical thoughts in his treatise named *Perspectiva*, utilizing mostly from Alhazen, treating the same optical topics with the same fashion of him. Apart from Alhazen he used the treatise *Optica* of Ptolemy in reproducing his table of refraction and Hero's principle of minimum distance mentioned in his *Catoptrica* in explaining refraction at equal angles. Witelo also seems to have used the treatise named *De speculis comburentibus* attributed to Alhazen to draw his analysis of paraboloidal mirrors and his treatise reveal the fact that Witelo was familiar with the *Optica* of Euclid, *Catoptrica* of Pseudo-Euclid, *De aspectibus* of al-Kindi and the

---

<sup>91</sup> A. C. Crombie, J. D. North, "Bacon, Roger", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 1, p. 379.

<sup>92</sup> David C. Lindberg, "Pecham, John", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 10, pp. 474-475.

physiological and psychological works of Galen, Hunayn ibn Ishaq, Avicenna, Averroes, the treatise of Robert Grosseteste named *De lineis angulis et figures*, the treatise of Roger Bacon named *De multiplicatione specierum* and Bacon's *Opus maius* and also John Pecham's *Perspectiva communis*. Witelo defines light as the first of all sensible forms so according to him light is an intermediary in certain natural actions. Witelo, following Grosseteste and Bacon states that every natural body propagates its power to surrounding bodies of which propagation of light is the principle example. He also followed Grosseteste and Bacon in concerning optics as the fundamental science of nature. Witelo states that light propagates rectilinearly all the time unless it encounters a reflecting or refracting surface. However he departs from Alhazen and Bacon by arguing that light requires no time for propagation through an extended medium. Following Alhazen Witelo departed from Grosseteste, Bacon and Pecham claiming that visual perception occurs due to the light and color issuing in all directions from every point of the visible object and entering the observer's eye to produce sensation. He also followed Alhazen defining the glacial humor as the sensitive organ of the eye.<sup>93</sup>

### 3.1.2. Theories on Reflection and Refraction

Grosseteste discussed the laws of reflection and refraction and their causes in his treatise. He used Ptolemy's rules and construction with plain surfaces to explain refraction by a spherical burning glass. His consideration of the concept of power and its production of the senses can be understood from his explanations of the formation of color. He states three principles, as the first is color is light incorporated by a transparent medium, the second is transparent mediums vary in degrees of purity from earthy matter, and the last one is light vary in brightness and in the multitude of its race. He adds that the intention and remission of these three principles cause the formation of the sixteen colors ranging from white to black. His last essay named *De iride seu de iride et speculo* is the most important contribution of Grosseteste to optics. He states an original law of refraction claiming that the refracted ray on entering a denser medium bisects the angle between projection of incident ray and the perpendicular to the interface. He claims that the size of the angle in the refraction of a ray may be determined in this way and he presents with his

---

<sup>93</sup> David C. Lindberg, "*Witelo*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 14, pp. 458- 460.

experiments of reflection that the reflection of a ray upon a mirror takes place at an angle equal to the angle of incidence.<sup>94</sup>

Roger Bacon provided eight rules to classify the properties of convex and concave spherical surfaces with the eye in various relationships to the refracting media. In order to do this, he cited from Ptolemy while examining plain surfaces and he cited from Alhazen while examining convex refracting surfaces. Roger Bacon explained Alhazen's statement of the eye as an image-forming device and so he made an important contribution to the history of physiological optics in the west. He based his ocular anatomy on Hunayn ibn Īshaq and Avicenna and so he introduced a new concept to laws of nature named *leges communes nature* which is referencing to the laws of reflection and refraction.<sup>95</sup>

Apart from his theory of direct vision Pecham briefly discussed the doctrine of species treated at length the propagation of race and developed a theory to explain how solar radiation when passing through noncircular apertures gives rise to circular images. Pecham explained the full law of reflection and applied it to the image formation by plain, spherical, cylindrical, and conical mirrors. He examined the focal point of a concave mirror during these applications. Pecham applied the general principles of refraction to the images that resulted from refraction at plain and circular interfaces between transparent media of various densities without developing any mathematical rule for refraction. Pecham compromising the theories of the formation of rainbow presented before him states that all three kinds of rays that are rectilinear reflected and refracted are involved in the formation of the rainbow. Pecham's importance in the history of optics is that he compressed the teachings of perspective into concise summaries as he expressed this as a goal of him in his treatise *Perspectiva communis*. *Perspectiva communis* is a very extant and comprehensive textbook including more than sixty manuscripts and going through twelve printed editions between the years 1482-1665. And this treatise is cited by many medieval and Renaissance natural philosophers. Lindberg states about the *Perspectiva communis* as the most widely used of all optical text from the early 14th until the close of the 16th century and he claims that the *Perspectiva communis* is still the best index of what was known to the scientific community in general on the subject.<sup>96</sup>

---

<sup>94</sup> Crombie, pp. 552- 553.

<sup>95</sup> Crombie, North, p. 380.

<sup>96</sup> Lindberg, pp. 475-476.

Witelo devoted the fifth, sixth, seventh, eighth and ninth books of his *Perspectiva* to the science of catoptrics. He used the three principles of reflection, that these are; the shortest lines connecting two points and the reflecting surface are those that make equal angles with the surface, the plane formed by the incident and reflected rays are perpendicular to the surface of reflection and thirdly that an object seen by reflection appears to be located where the backward extension of the ray incident on the eye intersects the perpendicular dropped from the visible object to the reflecting surface. Using these three principles of reflection and rules of geometry, Witelo achieved to solve a series of complicated problems of reflection generated initially by Ptolemy and Alhazen. Hence his most comprehensive explanations remain to be in the part of reflection in his *Perspectiva* and the optical knowledge of his catoptrics was not excelled until the 17th century in the West. He devoted the book 10th of the *Perspectiva* to the subject of refraction of light. Apart from the principle phenomena of refraction Witelo presented a mechanical explanation of refraction based on the varying resistance offered to the passage of light by different transparent substances. Hence Witelo resolved the oblique motion of light into components perpendicular and parallel to the refracting interface. His importance in the history of optics is that, along with John Peckham's *Perspectiva communis* the writings of Witelo served as a standard text book on optics until the 17th century.<sup>97</sup>

## 3.2. The Development of Modern Optics

### 3.2.1. Theories on Direct Vision

The first of the physiological researches of Leonardo Da Vinci (d. 1519) was his examinations on vision. He developed a model to describe the spread of light from its source and Leonardo Da Vinci used the intersection of waves dropped into a pond as his analogy to explain the spread of all powers produced by percussion as light and sound. He described light as circles emerging from the surfaces of the object and reaching through the eye with constant decay of power. As a result Leonardo Da Vinci explained the spread of light using the base of a pyramid which is decreasing in power as it reaches to any height

---

<sup>97</sup> Lindberg, pp. 460- 461.

of the pyramid. As the spreading light image reaches the pupil, it finds a circle expanding with the power of light and forming the base of another pyramid of light rays directed by refraction through the lens system of the eye to the optic nerve.<sup>98</sup>

Kepler's (d. 1630) observations in astronomy resulted as his interest to optics. He constructed a pinhole camera following the instructions of Tycho Brahe (d. 1601) and these observations directed him to a clear definition of the concept of the light ray. As a result Kepler is credited for the foundation of modern geometrical optics. For the first time Kepler showed that the image is formed on the retina of the eye and introducing the expression "pencil of light" he claimed that the light rays draw the image upon the retina.<sup>99</sup>

Descartes described the nature of light in his *Dioptrique* not as a motion which takes time, but rather a tendency to motion, an impulsive force transmitted rectilinearly and instantaneously by the fine particulars that fill the interstices between the visible macrobodies of the universe.<sup>100</sup> He claimed the instantaneous propagation of light, as a result of his conception of the medium serving as the vehicle of light. According to him, the nature of a corporeal substance consists solely in its being extended, and this extension is attributed mainly as the empty space. So there comes the conclusion that two equally extended bodies must have the same substance of matter and that the same part of matter can't have variable extension. Hence, according to Descartes, in such an incompressible and inelastic medium pressure must be transmitted spontaneously. Newton, later opposed this idea, claiming that an instantaneous propagation of motion had to involve a doctrine of infinite force.<sup>101</sup>

### 3.2.2. Theories on Reflection and Refraction

Kepler developed an expression for the angle of refraction as " $i - r = n \cdot i \cdot \sec r$ " where  $n$  is the index of refraction. This formulation of Kepler matched both with the erroneous data given by Witelo and the correct sine law of refraction of Descartes. By his treatise *Dioptrice* (1611), Kepler applied his principles of optics to the telescope. Kepler

---

<sup>98</sup> Kenneth D. Keele, "*Leonardo Da Vinci: Life, Scientific Methods and Anatomical Works*" **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 8, pp. 196-197.

<sup>99</sup> Owen Gingerich, "*Kepler, Johannes*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 7, p. 298.

<sup>100</sup> Michael S. Mahoney, "*Descartes: Mathematics and Physics*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 4, p. 58.

<sup>101</sup> A. I. Sabra, *Theories of Light from Descartes to Newton*, Oldbourne Press, London 1967, pp. 55-56.

described the optics of lenses in his *Dioptrice* with great integrity that he also included a new kind of astronomical telescope with two convex lenses.<sup>102</sup>

Snell (d. 1626) is credited in the history of optics mainly by the discovery of the law of refraction of light rays. This theory which is named after him was the result of many years of working using books as Kepler's *Ad Vitellionem paralipomena* (1604) and Risner's *Optica* (1606) that both of which cited from Alhazen and Witelo. Even though the manuscripts of Snell is containing the law of refraction is lost, it was examined by Isaac Vossius (1662) and by Huygens. As Huygens commented on it in his *Dioptrica* (1703, 1728) Vossius was the one who presented Snell's law of refraction to the literature of science.<sup>103</sup>

Presenting a model of tennis ball striking a flat surface, Descartes tried to drive the laws of reflection and refraction. Descartes applied to this model the two fundamental principles of his theory of collusion, claiming that a body in motion will continue to move in the same direction at the same speed unless acted upon by contact with another body and secondly a body can lose some or all of its motion only by transmitting it directly to another. To explain the law of reflection, Descartes assumed the surface that the tennis ball collides with should be perfectly rigid and immobile. However to explain the law of refraction, Descartes altered the nature of the surface claiming that the ball should pass through the surface but it should lose some of its motion in doing so. Although there are some accusations that Descartes had plagiarized the law of refraction from Snell, it is clear that Descartes know the sine law of refraction. In his treatise *Meteores*, Descartes presented a mathematical explanation of both the primary and the secondary rainbows in terms of refraction and internal reflection of the sun rays in a spherical raindrop.<sup>104</sup> He obtained a large spherical glass vessel filled with water, stood with his back to the sun and held up the glass vessel in the sun's light. By moving the vessel up and down, he realized that a bright red color appeared in the vessel with an angle of approximately 42 degrees to the incident rays coming from the sun. Descartes gradually raised the vessel determining the angle each color would appear.<sup>105</sup> Descartes reached at his quantitative conclusions as a result of his derivation of the angles that the rainbow is seen with respect to the angles of the sun's elevation. Once again using his model of the tennis ball, Descartes explained

---

<sup>102</sup> Gingerich, p. 298-299.

<sup>103</sup> Dirk J. Struik, "*Snel, Willebrord*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 12, p. 501.

<sup>104</sup> Mahoney, pp. 58-59.

<sup>105</sup> Sabra 1967, pp. 62-63.

color in terms of a rotary motion of the ball the speed of rotation varying with color. Hence when passing through a prism those speeds would be differentiated as the colors would be as a result of refraction.<sup>106</sup> However, his explanations of the formation of colors by a prism wasn't successful, this would later be achieved by Newton.<sup>107</sup>

Fermat's (d. 1665) interest in geostatics, lead him to read Descartes' *Dioptrique* and he started his optical examinations with the critique of this work of Descartes. Fermat argued with the claim of Descartes that light travelled more quickly in a denser medium and he also argued with Descartes' law of refraction in total. He developed his own law of refraction basing it on two postulates. The first postulate is that the final speed of light varied as the rarity of the medium through which it passed and the second postulate is the nature operates by the simplest and the most expeditious of ways and means. This second postulate is known as the Fermat's principle.<sup>108</sup>

### 3.2.3. Theories on the Nature of Light

3.2.3.1. The Wave Model of Light. Grimaldi (d. 1663) is credited for the discovery of optical diffraction in the history of optics. He wrote a comprehensive treatise on light named as *A physicomathematical thesis on light, colors, the rainbow and other related topics in two books, the first of which adduces new experiments and reasons deduced from them in favor of the substantiality of light. In the second, however, the arguments adduced in the first book are refuted and the Peripatetic teaching of accidentality of light is upheld as probable.* In the title page of this treatise it is also stated that it is dealt with "the previously unknown diffusion of light; the manner and causes of reflection, refraction and diffraction; vision and the intentional species of visibles and audibles; the substantial effluvium of the magnet, which pervades all bodies; and in special argument the atomists are attacked." In his book Grimaldi defines color as the modification of light and he attributes a fluid nature to the phenomena of light. His definition of diffraction remains the basis for his introduction of the fluid of light. Grimaldi prepared detailed experiments to

---

<sup>106</sup> Mahoney, p. 60.

<sup>107</sup> Sabra 1967, p. 67.

<sup>108</sup> Michael S. Mahoney, "*Fermat, Pierre de*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 4, pp. 574-575.

explain the concept of diffraction and by these experiments Grimaldi explored a new mode of transmission of light. This new mode of transmission of light revealed a contradiction with the rectilinear transmission of light, so diffraction brings the definition of the fluid nature of light. He names this new concept as diffraction as it's a loss of uniformity of the flow of a stream of water after an obstacle is placed in its path. Grimaldi explained the formation of color with attributing it to a "change in agitation" of the luminous flow. Proposing a light ray as a column of fluid in vibration, Grimaldi claimed that lighter colors occur with greater density of rays and darker colors occur with the lower density of rays. Both Hook and Newton utilized the optical works of Grimaldi in terms of developing their own definitions for the concept of diffraction.<sup>109</sup>

Ole Christensen Roemer (d. 1710) is credited in the history of science for the first quantitative measurements of the speed of light that he made in 1676. Till the ancient ages many claims had been asserted for the speed of light, for example Aristotle claimed that light propagated itself spontaneously. Later Kepler and Descartes shared this idea. Galileo, for the first time, opposed this idea and designed an experiment to present that light had finite velocity. Roemer, being acquainted to all of these ideas, organized an observational work where he noticed that the eclipses of Io occurred at longer intervals as the earth receded from Jupiter, but happened in closer sequence as the earth approached to Jupiter. Hence Roemer tried to predict the time of occurrence of an eclipse of Io beginning from the point at which the earth and Jupiter were closest to each other to the point where they drifted apart further. As a result, he signified that the eclipse predicted for 9 November of that year would be ten minutes later than the calculations made from previous eclipses would indicate. This phenomenon was presenting the finite velocity of light, that Roemer claimed it would take eleven minutes for light to reach the earth from the sun, resulting a speed value of 140,000 miles per second. This calculation of Roemer wasn't internalized by everyone at that moment, as Descartes's claim of instantaneous propagation maintained its validity for another while. However, it was after the discovery of James Bradley (d. 1762) of the periodic annual displacements in the positions of all stars in respect to the ecliptic, that Roemer's success was understood. Bradley calculated the time value for light

---

<sup>109</sup> Bruce S. Eastwood, "*Grimaldi, Francesco Maria*", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 5, pp. 543-544.

to reach earth from sun as eight minutes and twelve seconds in 1729, more accurately than Roemer.<sup>110</sup>

Christian Huygens (d. 1695) was the greatest mechanists of the seventeenth century who combined Galileo's mathematical treatment of phenomena with Descartes's vision of ultimate design of nature. He is also credited for the development of physical optics via his treatise *Traite de la Lumière*.<sup>111</sup> Studies of Huygens in geometrical optics are presented in his treatise *Tractatus de refractione et telescopiis*. His basic studies were on the law of refraction, the determination of the focuses of lenses and spheres and of refraction indices, the structure of the eye, the shape of lenses for spectacles, the theory of magnification and the construction of telescopes. He developed a theory claiming that in an optical system of lenses with collinear centers the magnification is not changed if the object and eye are interchanged. He applied this theory to telescopes and later used in his calculations for the "Huygens ocular" that has two lenses in it. He studied spherical aberration in 1665, which was a subject known since Kepler, claiming that the middle of a lens having spherical surfaces had not exactly the same focal length as the peripheral part of the lens. He realized that spherical aberration increases with the amount of deviation occurring and so it was advantageous using two lenses at the eye-piece of a telescope dividing the total deviation in those two.<sup>112</sup> He concluded with determining the shape of a lens with prescribed aperture and focal length which exhibits minimal spherical aberration of parallel entering rays. He studied chromatic aberration in 1668 not with his own experimental results like he did in spherical aberration but with the results of Newton's studies. There he concluded determining the most advantageous shapes for lenses in telescopes of prescribed length. Huygens also examined the effects of different variables on microscopes like, magnification, brightness, depth of focus and lightning of the object.<sup>113</sup>

Huygens developed his wave theory of light defining light as an irregular series of shock waves which proceeds with very great, but finite velocity through the ether and this ether consists of uniform, elastic, compressed particles.<sup>114</sup> There was no movement of translation here, contrary to the corpuscular theory and this theory explained how two light

---

<sup>110</sup> Zdenek Kopal, "Römer, Ole Christansen", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 11, p. 526.

<sup>111</sup> A. E. Bell, *Christian Huygens and The Development of Science in the Seventeenth Century*, Edward Arnold Press, London 1947, p. 9.

<sup>112</sup> Bell, pp. 170-171.

<sup>113</sup> H. J. M. Bos, "Huygens, Christiaan", **DOSB**, Charles Scribner's Sons Press, New York 1981, v. 6, p. 603.

<sup>114</sup> Bos. p. 609.

rays could travel in opposite directions in the same space. Also, it led to the famous conception of Huygens, secondary wavelets, that each particle in the path of a disturbance had a centre from which the disturbance spread outwards through all the particles in contact.<sup>115</sup>

After completing his theory of the wave nature of light, he adapted his theory to the explanations of reflection and refraction. Using his theory, he connected the index of refraction with the velocities of light in different mediums and he concluded in explaining the double refraction in Iceland spar. Huygens also calculated the refraction of rays on plane sections of the crystal. Huygens described the polarization effect in his first studies on the crystal but he couldn't develop an overall explanation to polarization.<sup>116</sup>

3.2.3.2. The Particle Model of Light. Newton (d. 1727) is known with his studies in optics, by his published letters related to light and color stated in *Philosophical Transactions*, his invention of a reflecting telescope and “sextant”, and his published treatise *Optics*. He obtained a triangular glass prism and started the examination of the phenomena of colors. As light from a tiny hole in shutter passed through the prism, the multicolored image wasn't in a circular form as Newton would expect from the laws of refraction but it was in an oblong form. This unexpected result led Newton to his famous “experimentum crucis”, where he used two prisms. As a result of his experiments with two prisms Newton came into the conclusion that light itself is a heterogeneous mixture of differently refrangible rays. Newton claimed an exact correspondence between color and the degree of refrangibility and he stated that while the least refrangible rays are in red color, the greatest refrangibility is attributed to the color deep violet. So opposing to the former idea that is stating colors as the qualifications of light derived from refractions or reflections of natural bodies, Newton claimed that colors are original and connate properties differing in different sorts of rays.<sup>117</sup>

Newton wrote his “*Hypotheses Explaining The Properties of Light Discoursed of in My Several Papers*” and in this hypothesis assuming the existence of an aetherial medium, Newton defined light as something capable of exciting vibrations in the aether. He used this concept of aether vibration for explaining the refraction, reflection, transparency and

---

<sup>115</sup> Bell, pp. 178-179.

<sup>116</sup> Bos. p. 610.

<sup>117</sup> I. B. Cohen, “*Newton, Isaac*”, **DOEB**, Charles Scribner's Sons Press, New York 1981, v. 10, p. 53.

opacity, the production of colors and the diffraction phenomena. Newton presented his main discoveries and theories about light and color in the *Optics* beginning with eight definitions and eight axioms. Of these some of the propositions are that “Light which differ in color differ also in degrees of refrangibility.” , “ The light of the sun consists of rays differently refrangible.”, the sine law holds for each single color contrary to the opinions of previous writers, and using this properties of light to explain the colors of the rainbow. Descartes developed a geometrical theory about the formation of the rainbow using the single index of refraction in his computation of the path of light through each raindrop. However Newton computed the radius of the bow of each separate color. In the conclusion part of the first edition of the *Optics* (1704) there is a set of 16 quarries and these quarries were considered the most important feature of the *Optics* in the 18<sup>th</sup> century and after. These 16 quarries are experiments of Newton organized in order to examine the concept of diffraction. The first of these quarries is about Newton’s claim that bodies act on light at a distance to bend the rays, the second and the third quarries are about the correlation with the differences in refrangibility and the differences in flexibility and they are about the bending that may produce color fringes. In quarry 4 Newton developed a single principle claiming that by acting variously in various circumstances; reflection, refraction and inflection might be produced where he suggested that the bending begins before the rays arrive at the bodies. Quarry 5 is about the mutual interaction of bodies and light where the bodies of light are objected to a vibrating motion. In quarry 6, Newton tried to explain the reason that black bodies conceived heat more easily from light than those of other colors and he discussed the action between light and sulphurous bodies, the causes of heat in friction, percussion, and putrefaction. In quarry 9, Newton defined the concept of fire and in quarry 10 he defined the concept of flame discussing various chemical operations. In quarry 11, he examined the heat and vapor of the sun and stars. In quarries 12 to 16, Newton associated visual perception with vibrations, that according to him vibrations cause sight by being propagated along the solid fibers of the optic nerves into the brain. In these last four quarries, he discussed the specific wave length of each color, binocular vision and the concept of persistence of vision.<sup>118</sup>

Newton, often being considered as the strongest defender of the emission theory of light, proposed a hypothesis of aether waves associated with this theory. Hence he

---

<sup>118</sup> Cohen, pp. 54-60.

proposes “Newton’s rings” as one of the strongest arguments for the periodicity of waves. While Hook (d. 1703) and Huygens denied the periodicity of light Newton postulated it as a fundamental property of waves of light. He also claimed in his quaries that vision might be the result of the propagation of waves in the optic nerves.<sup>119</sup>

---

<sup>119</sup> Cohen, p. 60.

## 4. THE ENTERANCE OF MODERN OPTICS TO OTTOMAN SCIENCE

### 4.1. The Establishment of the Engineer Schools in Ottoman State and the Imperial School of Military Engineering

Through the history, there are many examples of the close interaction between war arts and positive sciences. The innovation movement of the military of the Ottoman State that was started in the 18<sup>th</sup> century can be taken as an example of this interaction. The innovations in military enabled the entrance of positive sciences to Ottoman State and this was actualised due to the new institutions that had been established in 18<sup>th</sup> century.<sup>120</sup> The defeats that Ottoman State fell into against Europe from the beginning of the century, caused the impression that they fell behind at war technologies. As a result, Ottoman State initiated reforms and modernisation studies primarily at the field of technical training.<sup>121</sup> Janissary army who objected to innovations for various reasons tried to stop this movement by rebellions<sup>122</sup>. Within this period, dignitaries of the state tried to both sustain Janissary troops and maintain the military innovations by establishing new corps like the artilleries, bombardiers and miners to the order of the new war principles of Europe.<sup>123</sup>

#### 4.1.1. Bonneval Ahmed Pasha and the First Military Regulations

Bonneval Ahmed Pasha, who was an important contributor of the innovation movement, can be considered initially for the examination of the era of military

---

<sup>120</sup> Mustafa Kaçar, *Osmanlı Devleti'nde Bilim ve Eğitim Anlayışındaki Değişmeler*, Istanbul University the Institute of Social Sciences, PhD Thesis, Istanbul 1996, p. 1.

<sup>121</sup> Mustafa Kaçar, "Osmanlı İmparatorluğu'nda İlk Mühendishanenin Kuruluşu", *Toplumsal Tarih Dergisi*, issue 54, June 1998, p. 4.

<sup>122</sup> See. Abdülkadir Özcan "Patrona İsyanı", *Türkiye Diyanet Vakfı İslam Ansiklopedisi*, Volume 34, Türkiye Diyanet Vakfı Press, Istanbul 2007, pp. 189-192.

<sup>123</sup> Çağatay Ulusoy, Enver Kartekin, *Yüksek Mühendis Okulu, Yüksek Mühendis ve Yüksek Mimar yetiştiren müesseselerin tarihi*, Istanbul Teknik University Library Press, Istanbul 1958, p. 12.

innovations in Ottoman State<sup>124</sup>. Though Bonneval Ahmed Pasha's (1675-1747) exact name had been Claude-Alexandre Comte, after taking refuge in Ottoman State he started being called with this name. Topal Osman Pasha<sup>125</sup> who was appointed in the 21th September of 1731, sent for Bonneval Ahmed Pasha to Istanbul to incorporate him to the reform movement that he planned to actualise on army and he assigned Bonneval Ahmet Pasha as the Head of the Bombardiers<sup>126</sup>. With the idea of creating a model of the reorganisation of the Ottoman army, Bonneval Ahmed Pasha was assigned to train bombardiers in a modern way. Bonneval Ahmed Pasha sent for three French royal experts to Istanbul with the approval of the French Government. These were Marquis de Mornai, Le Comte Ramsey and l'Abbee de Macarthy who were keen on being employed in the service of him. Beginning from the 4<sup>th</sup> February of 1734, Bonneval Ahmed was titled as Pasha as an award for his successful works. In the same year, Bonneval Ahmed Pasha, presented a report to the Padishah, titled as *The Project of Radical Changes in the Ottoman Army on the European Model* and stated his opinions at various areas like gathering soldiers, organisation and war tactics and including information about French and European army's training, equipment, shipping and maintaining.<sup>127</sup>

Bonneval Ahmed Pasha was assigned as the head of the bombardiers until his death in the 23th March of 1747. Besides the theoretical and practical education, he also enabled the practicing of new war techniques in the corps of bombardiers. Bonneval Ahmed Pasha set a model for tracing the new technology in the corps of bombardiers by developing a new kind of howitzer that is advanced than other howitzers used in Ottoman army which can throw the explosives further and cause less gunpowder wastage. Also in the same era, a treatise about military sciences including the subjects of military engineering, Artilleryy, military architecture, war arts and trigonometry was translated to Ottoman with the name *Fünunu'l-Harb*<sup>128</sup> (War Sciences) and was presented to Sultan Mahmud I.<sup>129</sup> According to Adnan Adıvar, it was the first work of modern mathematics that mentioned about

<sup>124</sup> Abdulkadir Özcan, "Humbaracı Ahmed Paşa", **TDVİA**, Vol. 18, Türkiye Diyanet Vakfı Press, İstanbul 1998, pp. 351-353.

<sup>125</sup> Abdulkadir Özcan, "Topal Osman Paşa", **TDVİA**, Vol. 41, Türkiye Diyanet Vakfı Press, İstanbul 2012, pp. 244-246.

<sup>126</sup> "In military terms, Khimbara is name of a bullet that is round shaped, and filled with explosive material. The people who use this bullet via howitzer were called as bombardierp." For further information see Ahmet Halaçoğlu, "Humbaracı", **TDVİA**, Volume 18, Türkiye Diyanet Vakfı Press, İstanbul 1998, pp. 349-350.

<sup>127</sup> Mustafa Kaçar, *Osmanlı Devleti'nde Bilim ve Eğitim Anlayışındaki Değişmeler*, İstanbul University the Institute of Social Sciences, PhD Thesis, İstanbul 1996, pp. 10-13.

<sup>128</sup> See. İstanbul University Central Library the Centre of Turkish Manuscripts, nr. 6852, vr. 196 a-b.

<sup>129</sup> Kaçar, pp. 29-30.

trigonometry in the Ottoman State and first work to be translated from a foreign language to contribute Ottoman military sciences.<sup>130</sup>

Bombardiers carry out the education activity as a teaching staff of five men, including an engineering tutor, a painting master and three classroom teachers. On the other hand, sergeant major of the troop and other officers also participated in hands-on training. After the head of bombardiers, sergeant major has the highest rank and with his title as “Muallim-i ilm ve fenn-i ateşbazi” he teaches the science of war arts. Engineer Selim<sup>131</sup>, who got his engineering education in Europe, had carried out as a sergeant major in the corps of bombardiers from 1735 to 1741 and he contributed to the corps by teaching the European-based war tactics to Ottoman Army. Another officer who was working as a teaching staff was the mufti of Yenişehir, Mahmud Efendi-zade Said Efendi<sup>132</sup> (Mehmed Said Efendi). He was a notable mathematician and an astronomer of his era and he was assigned in the second class of the corps of bombardiers. The first treatise of Mehmed Said Efendi that he wrote when he was a geometry teacher, was a book about production and usage of the gadget that he named as Rub’-ı Müceyyebü’l-Zülkavseyn<sup>133</sup>. Mehmed Said Efendi invented himself this gadget to calculate the distance of the target during the shots of khimbara. In this treatise, the detection of the distance of the target was determined with the method of calculating the unknown edge of a triangle where the other two edges and the angle between them are known. Here the unknown edge is considered as the target’s distance. In his second work which is named as *Pergar-ı Nisbenin Bazü Burhanı Beyanındadır*<sup>134</sup>, Mehmed Said Efendi showed that the detection of the target’s distance in khimbara shots can be determined in seven different ways by using triangles’ similarities. In his works, Mehmed Said Efendi showed Nasireddin Tusi’s *Tahrir-i Usul-i Öklides*<sup>135</sup> as a source, which is considered one of the basic works of Ottoman mathematics. Mehmed Said Efendi’s another work named as *Risale-i Sinüs li Mesahatü’l-Bu’ud*<sup>136</sup> is related with

<sup>130</sup> Adnan Adıvar, *Osmanlı Türklerinde İlim*, Remzi Kitapevi, İstanbul 1970, p. 184.

<sup>131</sup> In his Phd thesis, Mustafa Kaçar states that Mühendis Selim became a chief architect in 1738, in 1740 he resigned from the corps of bombardiers and in 1741 he was assigned to protect the tower of Belgrade. To see the works that Kaçar mentions about see. derkenar. Başbakanlık Osmanlı Arşivi Maliyeden Müdevver Defterler Tasnifi, nr. 5941, p. 110.

<sup>132</sup> Salim Aydın, “Mehmed Said Efendi (Müftizade-i Yenişehir)”, *Yaşamları ve Yapıtlarıyla Osmanlılar Ansiklopedisi*, Vol. 2, Yapı Kredi Kültür Sanat Press, İstanbul 1999, p. 185.

<sup>133</sup> Topkapı Saray Müzesi Kütüphanesi, Hazine, no.1753/3, 17 vr.

<sup>134</sup> TSMK, Hazine, no. 1753/10, 3 vr.

<sup>135</sup> Nasiruddin Tusi, *Tahriru Usuli’l-Hendese ve’l-Hisab*, Prepared by İhsan Fazlıoğlu, Türkiye Yazma Eserler Kurumu Başkanlığı, İstanbul 2012.

<sup>136</sup> TSMK, Hazine, no. 606/2, 2 vr.

the usage of “sinus apparatus” which was used in surface calculation, and *Risale fi'l-Hendese ve'l-Hisab*<sup>137</sup> is a work of him related with geometry and arithmetic. Also, there are four more works about astronomy that Mehmed Said Efendi wrote each one in Arabic.<sup>138</sup>

In conclusion, although the corps of bombardiers which revealed a new method of military training for Ottoman State couldn't be long-reaching and lost its function in decades after being established, it was important for being the first attempt for modernisation in European way. The new military education that was produced here was qualified for being a model for the new engineering schools which were going to be established in the forthcoming years.<sup>139</sup>

#### 4.1.2. Baron de Tott and the First Artillery School

Baron Françoise de Tott<sup>140</sup> (1733-1793), known for his servings for the policy of Ottoman State based on innovation and initiation to Europe, informally came to Istanbul from Crimea and tried to enter Ottoman State's service with his own efforts. He tried different ways to get the attention of Sultan Mustafa III and to be accepted by the palace.<sup>141</sup> When the Ottoman-Russian war that started in 1768, concluded with the complete destruction of Ottoman Navy at offshore of Çesme in the 7th July of 1770, the Ottoman Porte charged Baron de Tott to fortify and protect Dardanelles of Çanakkale from Russian Navy's entrance. Baron de Tott placed 11 batteries, that 5 of them on the Asian side and 6 of them on the European side of Dardanelles, to stop the Russians in Çanakkale and filled each battery with guns that each differs in size and number between 6 and 12. Thus, Russians couldn't obtain a result from their attack to Dardanelles.<sup>142</sup>

<sup>137</sup> Darü'l-kütübi'l-Mısıriyye, no. 4773, 15 vr.

<sup>138</sup> Kaçar, pp. 26-28.

<sup>139</sup> Kaçar, p. 31.

<sup>140</sup> Geza David, “*BARON de TOTT, François*”, **TDVİA**, Vol. 5, Türkiye Diyanet Vakfı Press, Istanbul 1992., 83-84.

<sup>141</sup> Baron Françoise de Tott required help from Murad Molla and M. Gobis in order to be accepted in palace and even if this demand wasn't accepted it reached till the Sultan. After a while, the Sultan demanded via Dr. Gibbs for the three volume treatise *Traite de l'Artillerie* on artillery which belongs to Baron de Tott. So Baron de Tott, in addition to this book, presented some of his drawings on war plans and a map of Russia. As a result of his efforts, the Sultan Mustafa the 3<sup>rd</sup> requested him to build a small school of artillery. See also, Kaçar, pp. 33-34.

<sup>142</sup> Kaçar, p. 35.

Baron de Tott contributed to Ottoman's technology transfer in the fields of artillery, pouring of gun and the construction of floating bridge. The reproduction of artillery carriages according to the determined standards of the French model, which had been initially produced with different measurements during his works at Çanakkale exemplifies the attempts of Baron de Tott's technological implementations.<sup>143</sup>

The first Artillery School in Ottoman State that was constituted to give education in a modern European style was established in 1772 Istanbul, by the order of Sultan Mustafa III and the efforts of Baron de Tott. Relying both on his mathematics and geometry background and also French government's book support Baron de Tott put himself in for educating the artilleries. Sultan Mustafa III who came to the artillery school in 4 January 1773 to observe the artilleries' education and their practices of shooting under the control of Baron de Tott, stated his pleasantness of the success of the artilleries. Despite his favourable efforts, the reason of Baron de Tott's short existence in the artillery school was his solitary acting at the management of the school.<sup>144</sup>

#### 4.1.3. Speed Artillery's Corps

The Artillery training, that is started in the artillery school which activated in 1772-73 faced some malfunctions since artilleries couldn't break their old habits. Due to the difficulty of deterring Ottoman Artilleries from their old habits, it was decided to establish a new Artillery troop that consisted of militias. The formation of speed Artilleries was the first implementation of the reform plans about the Ottoman Artilleries that had been mentioned in Baron de Tott's report of the 25th October of 1771 named "The thoughts about Ottoman Army's current situation and ways for improvement". Speed Artilleries were the Artilleries that use the speed guns which were produced with new techniques and can shoot more cannon balls in compare to the old guns. The Artillery Sergeant Aubert<sup>145</sup> who had just come from France was appointed to the head of this corps. In the 21th

---

<sup>143</sup> Kaçar, p. 38.

<sup>144</sup> Mustafa Kaçar, Tuncay Zorlu, Burak Barutçu, Atilla Bir, C. Ozan Ceyhan and Aras Neftçi, *Istanbul Teknik Üniversitesi ve Mühendislik Tarihimiz*, Istanbul Technical University Press, Istanbul 2012, pp. 57- 59.

<sup>145</sup> In his PhD theses Kaçar mentioned about Antoine Charles Aubert's birth date as 13 January 1745. Also he stated that Aubert joined artillery regiment in 1758 and he became a sergeant in 1766 after a four years education here. For the source see, Frédéric Hitzel, *Le Rôle des Militaires Français à Constantinople (1784-1798)*, Université de Paris –Sorbonne (Paris V), 1987, unprinted theses, p. 26.

January of 1774 Sultan Mustafa III passed away couple days later than the establishment of the corps, and his successor Sultan Abdülhamid I took a close interest in the improvement of the Artilleries.<sup>146</sup>

During the regency of Sultan Abdülhamid I (1774-1789) the studies on educating naval officers were increased, and with the efforts of Sadrazam Halil Hamid Pasha<sup>147</sup>, the innovation of the army and the navy was undertaken.<sup>148</sup>

#### 4.1.4. The Establishment of the Hendesehane

Hendesehane, the first corporation that gives engineering education in Ottoman State, was established in Tersane with the attempts of Kapudan-ı Derya Gazi Hasan Pasha<sup>149</sup> (1713-1790) who was one of the prominent and affective statesmen in the empire. This school that named as Hendese Class or Hendesehane, is mentioned in French documentations as “Ecole des Théories” or “Ecole des Mathématiques”. The object of the school was stated as “to raise people who knows geometry (hendese) and geography sciences in the Imperial Navy”. The school was an important step for both the Ottoman Modernisation and the Ottoman Military History.<sup>150</sup>

Hendesehane who was established at the 29th April of 1775 in Tersane under the supervision of Baron de Tott and in where the European sources were benefited for teaching mathematics and military engineering, had been the first example of the engineering schools that were established in the 18<sup>th</sup> century in Ottoman Empire. Hendesehane which gave predominantly the mathematics education unlike the Artillery School that was established in 1772, was transformed into naval engineering at the beginning of its establishment as a result of both the state’s urgent need for navy and the request of Kaptan-ı Derya Gazi Hasan Pasha. There are also books about navy, ships,

<sup>146</sup> Mustafa Kaçar, Tuncay Zorlu, Burak Barutçu, Atilla Bir, C. Ozan Ceyhan and Aras Neftçi, *Istanbul Teknik Üniversitesi ve Mühendislik Tarihimiz*, pp. 59-61.

<sup>147</sup> Kemal Beydilli, “Halil Hamid Paşa”, *TDVİA*, Vol. 15, Türkiye Diyanet Vakfı Press, İstanbul 1997, pp. 316-318.

<sup>148</sup> Ulusoy, p. 24.

<sup>149</sup> Mahir Aydın, “Cezayirli Gazi Hasan Paşa”, *TDVİA*, Vol. 7, Türkiye Diyanet Vakfı Press, İstanbul 1993, pp. 501-503.

<sup>150</sup> Mustafa Kaçar, “Tersane Hendesehanesi’nden Bahriye Mektebi’ne Mühendishane-i Bahri-i Hümayun” *Osmanlı Bilimi Araştırmaları, Atilla Bir Armağanı*, c. IX, sayı 1-2, 2007/2008, ed. Feza Günergun, İstanbul University Press. İstanbul 2008 p. 53.

construction and mathematics in Baron de Tott's booklist that he ordered from Paris to utilize in Hendesehane.<sup>151</sup>

When Hendesehane was first established in April 1775 Algerian Seyyid Hasan Hodja was assigned as the chief instructor. Seyyid Hasan Hodja had continued his duty in Hendesehane until he was assigned to the navy as the second captain by Kaptan-ı Derya Gazi Hasan Pasha in the 27th March of 1781. Later, Seyyid Osman Efendi<sup>152</sup>, who was going to continue his duty until 1792, was assigned on behalf of Seyyid Hasan Hodja. Dating from 1781, this institute started to being mentioned as "Mühendishane" as well as "Hendesehane" in Ottoman Empire's official documents.

Toderini<sup>153</sup>, who lived in Istanbul in 1781-1786 and during this time visited the Mühendishane where he called as "Académie", gave some information about Seyyid Osman Efendi, the teacher of the Mühendishane, and the training activities of the Mühendishane, in his book named *De la Literature des Turcs* which is published in 1789 in Paris<sup>154</sup>. On the other hand, Toderini gave valuable information about many tools and books used in Mühendishane that are related with astronomy and navigation. For instance, in his book he mentioned about two celestial spheres one of them is Ottoman and other one is French made, a large number of astrolabes, Turkish and European gnomons, a beautiful octant which is made by a British named Jean Hadley, various Turkish compasses, azimuth circle, Irvin stool and other naval gadgets existing. He also indicated an Asian map printed on silk in the second room of the Mühendishane, old and new types of distance measuring equipment, a telescopic quadrant and various trig rulers. Toderini cited Katip Celebi's *Cihannüma* and the Turkish translation of M. Lalande's *Astronomy Tables* among so many Turkish and French books, and also referred to ballistic tables that were translated from French and shown him by Seyyid Hoca, he referred to the books that were written in

<sup>151</sup> Mustafa Kaçar, *Osmanlı Devleti'nde Bilim ve Eğitim Anlayışındaki Değişmeler*, Istanbul University the Institute of Social Sciences, PhD Thesis, Istanbul 1996, pp. 96-97.

<sup>152</sup> In Kaçar's PhD theses it's stated that Toderini met with the teacher Seyyid Osman Efendi during his visit to Mühendishane and that Seyyid Osman Efendi was born in Istanbul. For the source of Kaçar See; BA, MD, nr. 8882, p.84.

<sup>153</sup> Giambattista Toderini was a reverend and literature teacher who was born in 1728 Italy Venice. In 1781-1786 he researched about literature in Istanbul. For his Turkish translated work see. *İbrahim Müteferrika Matbaası ve Türk Matbaacılığı*, (Translator: Rikkant Kunt) Tifdruk Matbaacılık, Istanbul 1990

<sup>154</sup> For the Turkish translation of the work see. Ali Berktaş, *Türklerin Yazılı Kültürü (Türklerin Edebiyatı)*, Yapı Kredi Yayınları, Istanbul 2012.

Turkish about astrolabes, gnomons and compasses and the geometry books that were prepared for students.<sup>155</sup>

#### 4.1.5. Lafitte-Clavé and his importance in the Ottoman Reform

Engineer Major Lafitte-Clavé, who was graduated from Mezieres Royal School of Engineering, came to Istanbul from France in 1784 and served here more than four years. Lafitte-Clavé, prepared many plans, maps and reports after his three research expeditions which two of them were to the fortresses of the coasts of the Black Sea and other one was for the Bosphorus of Istanbul. The reports were used by his country for the recognition of the area and they were also very important resources for Ottoman's military fortresses in the Black Sea.

Lafitte-Clavé's secondary important activity was his theoretical military engineering classes that he gave with Gabriel Monnier in the Mühendishane. He showed the practical applications of this education on the models that he had them made around the Aynalıkavak Pavilion. Lafitte-Clavé's mathematics and military engineering lectures were twice a week on Tuesday and Friday, for a group of people numbered between 10 and 12. Also his book, named *Elements de Castrométation et de Fortification Passagère* was translated into Turkish with the name of *Usülü'l-Maarif fi Tertib-i Ordu ve Tahsinihi Muvakkaten* and published in 1787 at the printing house in the French Embassy Palace. Lafitte-Clavé who served in many military projects of Ottoman State and carried out so many activities successfully, was promoted to the degree of colonel when he went back to his country. Lafitte-Clavé was a talented and wise military engineer who usually gave his all to Ottoman Empire's military reform works, with the order of his own government and he also attended to the war of Özi in 1787. Lafitte-Clavé has a very important place in Ottoman's history of science with his contributions to education activities in Mühendishane and his works which involves the latest European techniques in military engineering.<sup>156</sup>

Besides Lafitte-Clavé and Gabriel Monnier, there are also Antoine Chabeaux and Sergeant Aubert who came to Ottoman for the second time with Artillery Sergeant Granpen to educate speed Artilleries. Engineer Lorca and his assistant Durest were

---

<sup>155</sup> Kaçar, pp. 101-102.

<sup>156</sup> Kaçar, p. 84.

appointed to the fields of shipbuilding and shipyard and Fransuva Aleksi and Betolen were appointed to the fields of foundry and armoury.<sup>157</sup>

According to Fazlıođlu, usage of the word “Mühendishane” by Ottomans reveals the determination of Ottomans of the significance of mathematical methodology in Western Science. They realized that this new form of science is based on quantity, experiment and observation rather than the education of madrasahs based on logic.<sup>158</sup> In the Mühendishane, an education based on mathematics and military engineering was given by Lafitte-Clavé. As Lafitte-Clavé stated, Jean François Callet’s book *Les Tables logarithmiques* was among the works of mathematics. And also among the other works of mathematics of Mühendishane there were Bezout’s *Cours de Mathématiques a l’usage du Corps Royal de l’Artillerie* (Paris 1770-1772, 4 volume) and his *Cours de Mathématiques a l’usage des Gardes du Pavillons de la Marine* (Paris 1764-1769, 6 volume). The books that are related with astronomy were Jacques Cassini’s *Elements d’Astronomie*, (Paris 1740) and J.J. Françoise de Lalande’s *Traite d’Astronomie*. These works indicate that algebra, geometry, trigonometry and in some level astronomy were taught for Artillery and naval. Also one of the French officers M. Tondu gave lectures about cartography which is one of the practical sciences and he taught the usage of naval clock and the drawing of a map using a compass and also the usage of a graphometer.<sup>159</sup>

While foreigner experts served in practical fields, theoretical lectures were given by Turkish teachers and geometry and arithmetic lectures were given by Gelenbevi İsmail Efendi<sup>160</sup> and Kasapbaşı Zade İbrahim Efendi. Although it was assumed that the movement might have been stopped after Halil Hamid Paşa’s removal who was a defender of the application of the western ideas and methods, Sultan Abdülhamid I enabled the school to function until the campaign of Ottomans to Russians in 1787.<sup>161</sup>

In the campaign of 1787, Russians and Austrians allied against Ottomans. These two allied countries assumed the reclamation of the Ottoman army and the Ottoman navy against themselves and they convinced the French King Louis XVI to send for the engineer and officers to their own countries. In 1788 French experts had left the Ottoman State but

<sup>157</sup> Ulusoy, p. 25.

<sup>158</sup> İhsan Fazlıođlu, “XVIII. Yüzyıl Osmanlı Düşüncesinde Bunalım ve Arayış- II Felsefe-Bilim”, Bülten - Bilim ve Sanat Vakfı, Evaluation : Eyüp Süzgün, Issue 67, 31 May 2008.

<sup>159</sup> Kaçar, p. 107-108.

<sup>160</sup> Şerafettin Gölcük-Metin Yurdağür, “Gelenbevi”, **TDVİA**, vol. 13, Türkiye Diyanet Vakfı Press, İstanbul 1996.

<sup>161</sup> Ulusoy, pp. 25-26.

even after their departure the school caught up on its activities and with the assignment of Kasapbaşızade İbrahim Efendi as the chief instructor the studies were continued. After him, in turn Gelenbevi İsmail Efendi and Palabıyık Mehmed Efendi were assigned as the chief instructors of the Mühendishane.<sup>162</sup>

The development of the Mühendishane was accentuated a lot and the Padishah himself followed the implementations and drills to make sure of the qualification of the education given. All in all, the Mühendishane represents the centre of Ottoman State's innovation and modernisation movement. The Mühendishane was reorganized in 1789 and started being called as Mühendishane-i Bahri-i Hümayun (The Imperial School of Naval Engineering). Mühendishane-i Bahri-i Hümayun constitutes the basis of both the Maritime College that educate captains and the Naval Academy that are still activating the present day.<sup>163</sup>

#### **4.1.6. Mühendishane-i Bahri-i Hümayun (The Imperial School of Naval Engineering)**

Selim III, who succeeded to throne after the death of his uncle Sultan Abdülhamid I in 28 March 1789, encountered with French Revolution. The new climate of Western, where the scientific continuity proceeds swiftly and the new values replace the old ones, made the transfer of knowledge an obligation for the Ottoman State via the new societies that were established.<sup>164</sup>

Selim III, who was raised by being included to political events since his childhood both by his father Sultan Mustafa III and his uncle Sultan Abdülhamid I, aimed big progresses at the state structure, the army and the education and consequently he could attain some of his aims. For instance, the constitution of the permanent embassies in western countries was founded during his reign. Selim III had started a reform process that provided very important outcomes for the Ottoman Empire.<sup>165</sup> As soon as he succeeded to throne he started reform movements despite the continuing war against Russia and

---

<sup>162</sup> Ulusoy, p. 26.

<sup>163</sup> Aykut Kazancıgil, *Osmanlılarda Bilim ve Teknoloji*, Gazeteciler ve Yazarlar Vakfı Press, İstanbul 1999, p. 256.

<sup>164</sup> Kazancıgil, p. 251.

<sup>165</sup> Kazancıgil, pp. 251-252.

Austria<sup>166</sup>. Also in 1791 and 1792, he demanded reports from the high state officials about their opinions about the reforms to accomplish the reforms in a good way.<sup>167</sup>

Mühendishane-i Bahri-i Hümayun was established in 1773 and started giving education according to mathematical principals. However, the fact that the students had knowledge about galley construction and cartography caused a gap in the army. To fill this gap, a new school was established under the name of Mühendishane-i Sultani. The facts that in Mühendishane-i Sultani only theoretical courses were featured and it didn't have the capacity of too much students resulted in its integration with the barracks of bombardiers in Hasköy. Hence, a new and separate school was started to be established.<sup>168</sup>

The code of laws that rearranges the corps of the bombardiers which was established in 1735 in Üsküdar, was published on 27th September of 1792. Thus, on 14th July of 1793 in Hasköy, new corps of bombardiers and miners was founded. The fact that the corps of bombardiers and miners being found more necessary and important than other military corps provided extra attention given on the education of geometry and engineering during the reorganization of the corps. The corps of bombardiers and miners had been placed into sheds in Kağıthane until the barracks' construction were over and also a temporary Mühendishane had been built in this sheds during this interval. This institute that hadn't been named during its establishment later was named as Mühendishane-i Berri-i Hümayun (The Imperial School of Military Engineering).<sup>169</sup>

A chief instructor and three assistant instructors, who were selected from Tersane Engineer School sternly to the laws of 1792, were assigned as the engineer school's teaching staff. From those who were assigned; Abdurrahman Efendi became the chief instructor of the engineer school, Hüseyin Efendi<sup>170</sup> (Hüseyin Rıfki Tamani) became the second instructor and Bosnian Osman Efendi became the third.<sup>171</sup>

---

<sup>166</sup> When Selim III acceded, Ottoman Empire was in war with both Austria and Russia. Those wars were ended with the Svishtov Agreement made with Austria in 1792 and Yaş Agreement made with Russia. See. Kemal Beydilli "Ziştovi Antlaşması" TDVİA, vol. 44, İstanbul 2013, pp. 467- 472 and See. Kemal Beydilli "Yaş Antlaşması" TDVİA, vol. 43, İstanbul 2013, pp.343-347.

<sup>167</sup> Kaçar, p. 111.

<sup>168</sup> Ulusoy, pp. 34-35.

<sup>169</sup> Kaçar, pp. 112-115.

<sup>170</sup> Salim Aydüz, "Hüseyin Rıfki (Tamani)", **YYOA**, volume 1, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul 1999, pp. 591-592.

<sup>171</sup> Kaçar, pp. 115-116.

Küçük Hüseyin Pasha<sup>172</sup> who was the milk sibling of Sultan Selim the 3<sup>rd</sup> and was assigned as Kaptan-ı Derya on 10th March 1792, attained to new activities especially about the modernization of the navy. Firstly, dealing with the Tersane Engineer School he tried to bring in a new order here and he wanted to transform the engineer school to a naval engineer school where the subjects of shipbuilding, geography and land surveying were taught. Jacques Balthazard le Brun, the shipbuilding engineer who was brought to Istanbul from France in May 1793 to serve Ottoman State, was immediately assigned as the head of the Tersane Engineer School and he started education activities in here.<sup>173</sup>

On 18th February 1797, in addition to “Fenn-i İnşa” branch, another branch named “Fenn-i Harita ve Coğrafya” was constituted in engineer school. On July 1797 the constitution of the barracks of the corps of bombardiers and miners and the new engineer school were completed and seven land engineers who had been in the teaching staff of Tersane Engineer School, were assigned to these new institutions. As a result, the education of land engineering in the Ottoman State was gathered in a single place. With the code of laws of 1806, Mühendishane-i Hümayun started being called as “Mühendishane-i Berri-i Hümayun” (The Imperial School of Military Engineering) and the Tersane Engineer School started being called as Mühendishane-i Bahri-i Hümayun (The Imperial School of Naval Engineering) and later times these names were used in official documents.<sup>174</sup> Thus, a new engineering school was established with the name of “Mühendishane-i Berr-i Hümayun” and the life of the old naval engineering school and the new land engineering school which both are still present today, started. Military engineering and Artillery classes of Mühendishane-i Berr-i Hümayun, constitute one of the foundations of today’s Turkish Military Academy. On the other hand, civilian engineering school that was established in 1833 represents the initiator of today’s Istanbul Technical University.<sup>175</sup>

Comparing with the Imperial School of Naval Engineering, the Imperial School of Military Engineering possesses broad opportunities in terms of gadgets, equipments, the library and other facilities. The foundries include all kinds of scientific modern teaching

---

<sup>172</sup> Yayın Kurulu, “*Hüseyin Paşa (Küçük)*”, **YYOA**, volume 1, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul 1999, p. 589.

<sup>173</sup> Kaçar, p. 117.

<sup>174</sup> Kaçar, p. 142 .

<sup>175</sup> Kazancıgil, p. 257.

equipments.<sup>176</sup> In 1803-1808 both the naval and the military engineers were managed monopoly and took classes from the same teachers. Moreover, sometimes students and assistants of lecturers from other engineer schools came to the Imperial School of Military Engineering and took classes together.<sup>177</sup>

In conclusion, naval engineering contractors and students took classes each Monday and Thursday by coming from Tersane to Hasköy and also they took the advantage of the new equipments. The fact that the school gathered the most precious and famous Ottoman scholars together and started educating towards the new principals were appreciated by Europeans and so many books were sent as gifts.<sup>178</sup>

However, since the Kabakçı Revolt in 1807<sup>179</sup>, innovation movements were stopped and Sultan Selim III was dethroned. After Kabakçı Revolt, Sultan Mustafa IV had acceded and governed the Ottoman Empire until his dethronement in 1808 by Alemdar Mustafa Pasha's<sup>180</sup> force. In the era of Sultan Mahmut II (1808-1839), who replaced the throne after Sultan Mustafa IV's dethronement, the renovation movements were maintained despite the whole internal and external threats that obstructed the management. In the era of Mahmut II, guild of janissaries was abolished in 1826 and afterwards in 1825 The Medical School and in 1834 Turkish Military Academy were established, thus education activities were accelerated. Besides, the civilian and military schools that were regulated, by organizing the teaching staffs of Mühendishane-i Berri-i Hümayun an engineer school named Mansure was constituted in 1825 to use in the army. On the other hand Bahri and Berri engineer schools' student capacity was increased.<sup>181</sup>

In 1834, 2 officer and 10 students from Mühendishane-i Berri were sent to England for making professional researches and studies. Among those people, there were famous painters as Ibrahim Pasha and Ahmet Emin Efendi<sup>182</sup>, the head of the Artillery department Hacı Hüseyin Rıfkı Pasha, famous chemist Derviş Pasha<sup>183</sup>, and Tophane-i Amire council head Eyüp Halid Pasha. As well as sending Turkish professionals abroad for studying,

---

<sup>176</sup> Ulusoy, p. 41.

<sup>177</sup> Ulusoy, p. 26.

<sup>178</sup> Ulusoy, p. 41.

<sup>179</sup> Kemal Beydilli, "*Kabakçı İsyanı*", **TDVİA**, volume 24, Türkiye Diyanet Vakfı Yayını, İstanbul 2001.

<sup>180</sup> Kemal Beydilli, "*Mustafa Paşa (Alemdar)*", **YYOA**, volume 2, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul 1999, pp. 306-308.

<sup>181</sup> Ulusoy, pp. 45-46.

<sup>182</sup> Ahmet Kamil Gören, "*Ahmed Emin (Servili)*", **YYOA**, volume 1, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul 1999, pp. 125-126.

<sup>183</sup> Salim Aydüz, "*Derviş Paşa (Kimyager)*", **YYOA**, volume 1, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul 1999, pp. 375-376.

foreigner experts and teachers were also called and assigned to engineer schools. In 1848, Engineer school had foreigner teachers like Mister Sang, Monsieur Blum, Monsieur Bon, Monsieur Gronvald in its teaching staff.<sup>184</sup>

In 1871, by moving the students of the military academy to Harbiye and Artillery students to a barracks in Maçka, engineer school was turned into a preparation school that only educates students who will become an Artillery and military engineering officer. Since the lack of place for wounded soldiers in 1877-1878 Russian war, the building in Hasköy was transformed to a military hospital. The building was used as a hospital during the war, and afterwards it was decided to resume the building as an Engineering School again. The building which was constructed by Selim III in Hasköy, was rebuilt properly to provide education. One of the famous mathematicians of the era Vidinli Tevfik Pasha<sup>185</sup>, was assigned as the Director of the Engineering School and Sezai Pasha was assigned as the Director of Classes. The return of the students from Harbiye to Hasköy was celebrated with a ceremony and Hasköy resumed on giving education.<sup>186</sup>

#### 4.1.7. The Curriculum of Mühendishane-i Berri-i Hümayun

When Mühendishane-i Berri-i Hümayun was first established, its whole teaching staff was consisted of four instructors and four Halife. The pioneer instructors of the engineer school Hüseyin Rıfki Tamani, Seyyid Ali Pasha<sup>187</sup>, İshak Efendi<sup>188</sup>, Abdurrahman Efendi, Ömer Efendi and Hasip Efendi were all scholars who knew foreign languages and have translated books from French and English to Turkish. Assistants of the teachers were called as “Halife” and to promote, all of the Halife and engineers had to pass an examination and write a Turkish thesis or translate a foreign work.<sup>189</sup>

In Mühendishane-i Berri-i Hümayun there was a director and in each class there was a teacher and his assistant. Teachers were classified according to the class they lectured and teachers of the senior class were called as “chief instructor”. It was conditioned for the

<sup>184</sup> Ulusoy, pp. 78- 97.

<sup>185</sup> Kazım Çeçen, “*Hüseyin Tevfik Paşa*”, TDVİA, volume 19, Türkiye Diyanet Vakfı Press, İstanbul 1999.

<sup>186</sup> Ulusoy, Kartekin, pp. 48-50.

<sup>187</sup> İhsan Fazlıoğlu, “*Seyyid Ali Paşa*”, YYO, Volume 2, Yapı Kredi Kültür Sanat Press, İstanbul 1999, p. 529.

<sup>188</sup> Salim Aydüz, “*İshak Efendi (Hoca)*”, YYO, Volume 1, Yapı Kredi Kültür Sanat Press, İstanbul 1999, p. 657.

<sup>189</sup> Ulusoy, pp. 65-71.

teachers to know at least one foreign language and to write a book. According to the law book of 1795, it was decided not to terminate the jobs of the teachers or the Halife unless they commit a serious crime, resign or die. This advanced job safety and scientific autarchy which were provided by Selim III, were avoiding the external oppression of the teaching staff and increasing and upgrading the education level. The foundation of the technical education in Turkey is based on these schools.<sup>190</sup>

The students, who had just registered to the engineer school, were given mathematics education initially and geometry education secondly by using *Müselles Risalesi* of Gelenbevi İsmail Efendi as a source. Apart from these, lessons like calligraphy and orthography, mechanical drawing, Arabic and French were also being taught. Gelenbevi's *Hesab-ı Küsur ve Cebr'i Mukabele Risalesi* was used as a lecture book and other than this *Usul-ı Hendese Risalesi*<sup>191</sup> which was translated from English and Lafitte-Clavé's *Ordu Tertibine Dair* were used during lectures. After finishing these books in lectures, books about modern war sciences ("*Sanayi-i Harbiyyeyi Müştemil Kütüb-i Fenniye*"), were being lectured.<sup>192</sup>

It was an important and a prior job to prepare and print the books and pamphlets that are necessary for the lessons in syllabus, with their translations and copyrights. Since the related works were all in foreign languages (especially in French, English and some of them in Arabic) it necessitates the priority of these works' translation and it is expected from the teachers to compile the copyrights of other works different than translations. Geography education that is given in secondary class continues in third class as well. And in third and fourth grades, students were offered a more extensive training program. Students study all kinds of engineering sciences that are based on calculus like conic sections, differential calculation, integral calculation, mechanics and astronomy related to measuring, mapping, fortified buildings construction, modern military order, Artilleryy,

<sup>190</sup> Emre Dölen, "*Mühendislik Eğitimi*", **Tanzimat'tan Cumhuriyete Türkiye Ansiklopedisi**, volume 5, İstanbul: İletişim Press, 1985, p. 512.

<sup>191</sup> *Usul-ı Hendese*, was written by English Engineer Selim Efendi, who came to İstanbul in the era of Selim the 3<sup>rd</sup> and served to Ottoman Empire between 1795-1808. He took lessons from John Bonnycastle, who was a mathematics professor in Royal Military Academy and this shows that he was educated in this academy. In 1797, he translated Bonnycastle's book *Euclid's 'Elements' with Notes* that was written in 1789 and was related with Euclidean geometry, to Turkish as *Usul-ı Hendese* with Hüseyin Rıfıkı Tamani. The translation's importance for Ottoman mathematics history is the fact that it's the first book that introduces the modern version of Euclidean Geometry to Ottoman. For further detail look at; Mustafa Kaçar "*Sultanın İsimsiz Kahramanları*" Osmanlı Bankası Arşiv ve Araştırma Merkezi, 12 Aralık 2007.

<sup>192</sup> Kemal Beydilli, *Türk Bilim ve Matbaacılık Tarihinde Mühendishane, Mühendishane Matbaası Ve Kütüphanesi*, Eren Yayıncılık, İstanbul 1995, pp. 59-60.

mining and military engineering. State's requirement in technical areas necessitates initial engineers to have knowledge and skills in every branch. Hence, they didn't specialize in any branch of the sciences that each one is a separate discipline. An engineer had to be enlightened in various branches.<sup>193</sup>

In technical schools that were established in the second half of the 18<sup>th</sup> century and in Mühendishane-i Berri-i Hümayun there weren't any physics lessons. Although in the law book of 1794, which aimed to reorganize the Mühendishane-i Berri-i Hümayun, it was stated that students would be taught "hikmet" (physics) and books about physics were given as gifts from Sultan Selim III to school's library, there weren't any physics lessons in syllabus. Instead of physics, mechanics which is a branch of physics that is related with the practical application of it were taught in these schools.<sup>194</sup> Physics courses were put into the curriculums of engineer schools in Ottoman State as late as the middle 19th century. Afterwards, solely physics related books were published and laboratory research which is one of the most important symbols of physics of 19th century was initiated.<sup>195</sup>

Another speciality and advantage of Mühendishane-i Berri-i Hümayun was that it had its own press. In 1769, a year after Mühendishane-i Berri Hümayun's establishment, press went into action and provided the printing of the school books, translated works, and precious books about geography and history.<sup>196</sup>

When Mühendishane-i Berri-i Hümayun transformed into Artillery and architecture school in 1847 some changes were made and four-year Artillery and architecture classes were opened. Schooling rather grouped and lessons like building, painting, applied architecture, topography, shipbuilding, road, bridge, canal and reservoir construction, chemistry, civilisation and French were taught. On the other hand secondary year program included physics lesson (hikmet-i tabii) in a broad sense.<sup>197</sup>

As well as foreigner experts and engineers, Madrasah based teachers were lecturing in engineer school and this shows that these new institutions that founded by the government and mainly the reform movement were supported by the madrasah members. Although there were custom differences between the ulama who continues madrasahs'

---

<sup>193</sup> Beydilli, p. 60.

<sup>194</sup> Emre Dölen, "*Bilim-Fizik*", **Tanzimat'tan Cumhuriyet'e Türkiye Ansiklopedisi**, volume 1, Istanbul: İletişim Yay, 1985, p. 178.

<sup>195</sup> Meltem Akbaş, *Osmanlı Türkiye'sinde Modern Fizik*, Istanbul University the Institute of Social Sciences, PhD Thesis, Istanbul 2008, p. iii.

<sup>196</sup> Ulusoy, p. 59.

<sup>197</sup> Ulusoy, p. 57.

classical Islamic education, and engineer and scholars who studied in new, modern, science-educating institutions they still maintained their activities compatibly.<sup>198</sup>

Dissimilarly to most of the Madrasahs that are connected with trust institutions, engineer schools that are established dependant on the state's budget are the first examples of western styled schools established in Ottoman Empire. One of the representations of the Ottoman-Western synthesis is the engineer schools. Examples to this synthesis are the organization of the education system that separates students into classes, the system of grading and promotion, and the books that are taught in the syllabus, providing a differentiation from madrasahs. While in the Ottoman Madrasah system "icazetname" (diploma) was taken from the teachers according to the success of the student during the lesson, in the new education institutions that are separated into four grades, graduation depended to pass the grades. Also there needed to be a vacancy in the higher grade for passing there to be possible. With these properties, engineer schools represent the syntheses of the Ottoman and European education system and as a result an important part of the European style of innovation in Ottoman State.<sup>199</sup>

#### 4.2. Life and Works of the Chief Instructor Ishak Efendi

Chief Instructor Ishak Efendi<sup>200</sup> was an important scholar who led the entrance of modern sciences that developed in Europe to Ottoman State. The broad and fast translation movement that Ishak Efendi carried out and the innovations and regulations he provided in the Mühendishane-i Berri-i Hümayun's education system enabled important developments in Ottoman science.

For the first time, author James de Kay mentioned about the scientific works of Chief Instructor Ishak Efendi while publishing his inspirations of the journey that he made to Turkey in 1831-32. Additionally, there are also biographical works of Faik Reşit Unat, M.Fuad Köprülü, Mehmet Şakir Ülkütaşır and Sait Arif Terzioğlu. However up to the present, the most comprehensive biographical work about Chief Instructor Ishak Efendi is

<sup>198</sup>Ekmeleddin İhsanoğlu, *Osmanlılar ve Bilim, Kaynaklar Işığında Bir Keşif*, Nesil Yayınları, İstanbul 2003 p. 214.

<sup>199</sup>İhsanoğlu, pp. 216-217.

<sup>200</sup>Ekmeleddin İhsanoğlu, "*İshak Efendi, Chief Instructor*", **TDVİA**, Volume 22, Türkiye Diyanet Vakfı Press, İstanbul 2000, pp. 529-530.

written by Ekmeleddin İhsanoğlu. In this article, mainly Ekmeleddin İhsanoğlu's biographical work is utilized while representing Chief Instructor Ishak Efendi's life.

Ishak Efendi was born into a Jewish family living in Narda town of Yanya which is located at the Albania border of Greece. Although any information about Ishak Efendi's birth date couldn't have been found up to present in the archives, Turkish works or in *Mirat-ı Mühendishane*, M. Franco stated the birth date as 1774 in his work. Despite losing their father in a very young age, both Ishak Efendi and his younger brother managed to complete their education. Before going to Istanbul, Ishak Efendi learned Arabic, Turkish, Farsi, Greek, Latin and French. There isn't any information about Ishak Efendi's education before he went to engineer school, however his language knowledge gives an idea about his education. While Ishak Efendi learned Hebraic in family circle and Greek in his home town, his knowledge of Turkish, Arabic and Farsi shows that he adopted Islam in an early age and had a good madrasah education.<sup>201</sup>

When Ishak Efendi came to Istanbul, he registered to Mühendishane-i Berri-i Hümayun and spent the years 1806-1815 with education. In that time, since the grading system was planned as the beginners were in fourth grade and the seniors were in the first grade and the student population was low in the engineer school, passing grades was organized in a hierarchy. Because of the fact that passing grades required both succeeding in the exams and also a vacancy in the higher class it took nine years for İshak Efendi to complete his last two years in the engineer school. Due to his sedulity, knowledge and intelligence during his education in engineer school İshak Efendi called chief instructor Hüseyin Rıfıkı Tamani's attention, who led the research of modern mathematics in Ottoman. When Tamani was assigned for the repairing of holy buildings in Medina in 1816, he took for İshak Efendi as an assistant. In documents that were submitted to Mahmud II, it is understood that Ishak Efendi who came to Istanbul after his duty in Medina, became a pupil to last grade with 45 kuruş salary in 1823-24. In the same way, Müderiszade Sa'dullah al-Ankaravi's statement about Ishak Efendi's taking arithmetic and geometry education while Sa'dullah al-Ankaravi was appointed as depute judge (naib) in

---

<sup>201</sup> Ekmeleddin İhsanoğlu, *Chief Instructor İshak Efendi Türkiye'de Modern Bilimin Öncüsü*, Kültür Bakanlığı Press, Ankara 1989, pp. 7-8.

Sütlüce in 1823 also shows that in that date Ishak Efendi was still continuing his education. However there isn't any information about his graduation date from engineer school.<sup>202</sup>

Ishak Efendi, who became a mathematics teacher in Mühendishane-i Berri-i Hümayun after his graduation, had two sons, named Sami and Bahai and a daughter. While studying in engineer school, Sami Efendi assisted his father by attending some of the lessons with him. Also he served as a translator in Divan and in engineer school. While Bahai Efendi passed away in his young age, Sami Efendi died after a while later his father's death. There isn't any information about Ishak Efendi's daughter except that she was married with Halil Esrar Efendi. When Ishak Efendi was assigned as the translator of the Imperial Council (Divan-ı Hümayun) in July of 1824, it was issued that just as Ishak Efendi himself, his son Sami Efendi and his son-in-law Halil Esrar Efendi were also put on salary. Ishak Efendi who became a translator of the Imperial Council in 1824, maintained his duty along with his duty in engineer school until 1829. The imputation that was claimed against Ishak Efendi during this period caused him to assign for restoration and control of the bulwarks in Balkans during the last months of 1829. While Ishak Efendi was doing his duty as the translator of the Imperial Council he was exposed to the same treatment with foreigner translators and the translation of documents that includes the secrets of government weren't given to him. As it came off in later reviews, Ishak Efendi who was sent away because of the imputation that arises from Reisü'l-küttab Pertev Efendi's enmity turned back to his duty in 1830. In the end of 1830, his assignment to the engineer school as the chief instructor was decided.<sup>203</sup>

Owing to his popularity that he gained for his great knowledge on mathematics and engineering, Ishak Efendi was sent to Medina as assistant of Chief instructor Hüseyin Rıfki while he was studying. He tutored the people who demanded from him and contributed to the improvement of Mühendishane-i Bahri and Berri-i Hümayun's training procedures. After chief instructor Hüseyin Rıfki Tamani's death, the chief instructor Seyyid Ali Efendi was suspended in order to avoid some malfunctions and disorders in Mühendishane-i Bahri-i Hümayun and Mühendishane-i Berri-i Hümayun and Ishak Efendi was assigned instead of him. When Ishak Efendi's assignment as a chief instructor was notified to him in

---

<sup>202</sup> İhsanoğlu, pp. 9-15.

<sup>203</sup> İhsanoğlu, pp. 8-18.

1830 December's last day, his former position which is the translator of the Imperial Council was given to his son Mahmud Sami Efendi.<sup>204</sup>

Ishak Efendi initiated a series of innovation as soon as he was assigned to the Mühendishane. Firstly, he dismissed unlicensed instructors and he tried to regulate the teaching of lessons.<sup>205</sup> In the last grade that Ishak Efendi was in charge of, there were 5 lessons being taught in the daily schedule that one of them was praxis. Each morning thirty six engineering applicant started to study on their own chairs in the library. Each day they were separated to groups of three people and wrote down the writings, calculations and shapes of the lesson on the black board of the classroom in turns. The teaching of the lessons were respectively as; the teacher giving the lecture, the student on call writing the lecture on board and then the students writing it down on their own board. Later, the instructor evaluated the lesson, the processes of the lesson were being done and finally doing question-answer styled exercises the lesson would be completed. Students would be resting in their rooms until the next lesson. The day was being started with a short translation of Bezout's French Maths book and the subject of hydraulics was being taught again from the same book. In second lesson, the parts that were related to mechanics in Ishak Efendi's *Mecmua-i Ulum-i Riyaziye* were being taught. The third lesson was in the afternoon and the book *İsagoci* of logic was being taught. In the fourth lesson, Ishak Efendi's own writing *Usul üs-siyağa* was being taught. The fifth lesson, which was praxis, was educated with one of the Halife's practising the lesson in the area with one chosen illustrator and ten students.<sup>206</sup>

During the interval of Ishak Efendi as a chief Instructor a series of innovation was brought into the education system and the engineer schools' equipment was fortified with new gadgets. The big black boards that İshak Efendi brought into classes for students to draw lessons' shapes and calculations and the personal writing boards for students to take notes are examples of these innovations. During his duty, in addition to his supplementation of education equipments and his innovations in the engineer school, İshak Efendi published so many books for science education by preparing their copyrights and translations.<sup>207</sup>

---

<sup>204</sup> İhsanoğlu, pp. 19-22.

<sup>205</sup> Sevim Tekeli, "Batılılaşmada son dönem: İshak Hoca", *Erdem*, c IV, sayı 11, Mayıs 1998, p. 442.

<sup>206</sup> İhsanoğlu, p. 22-24.

<sup>207</sup> İhsanoğlu, p. 24-25.

In 1834, while he was a chief instructor, Ishak Efendi assigned for the reparation of the holy buildings in Medina and Abdülhalim Efendi was assigned as the deputy in the Mühendishane instead of him. Ishak Efendi passed away in February 1836 during his trip from Medina to Istanbul. His memory was reminisced with an epitaph which is in cemetery near the engineer school in Hasköy, written “Divan-i Hümayun sabık serhalifesi ve Mühendishane-i Hümayun Başhocası el-Hacc Hafız İshak Efendi (The last leader Halife and the Chief Instructor of the Imparial School of Military Engineering, Haji, Hafız İshak Efendi). Era’s newspaper Takvim-i Vekayi, praised Ishak Efendi’s personality and referred him as era’s second Katip Celebi. Ishak Efendi had been a serious, hardworking chief instructor who was fond of his duty and was loved by his colleagues and students. His works have contributed a lot to Turkish science and education, and led the positive sciences’ entrance to Ottoman Empire. During his duty (1826-1834), he prepared ten books that have thirteen volumes and with those books he educated lots of scientists, including Chemist Derviş Pasha, Müşir Emin Pasha and Mirliva Esad Pasha who were going to make important studies on modern science in later periods.<sup>208</sup>

Except for his two books about war techniques, named *Rekzi ve Nasbu’l-Hıyam ve Tuhfetü’l-ümera fi Hıfz-ı Kıla* that he wrote while he was serving as a translator in Divan-ı Hümayun, Ishak Efendi wrote most of his works when he was serving as a chief instructor. His first work that he wrote during his duty as a chief instructor was *Medhal fi’l Coğrafya* that was published in 1831 and it was a summary of geography-related-parts of the astronomy book of Hüseyin Rıfkı Tamani who was the first chief instructor of the engineer school. Thereafter he had a work published in 1831-1833 named *Usul üs-siyağa* which was related with Artilleryy and was translated from a French book. Additionally, *Mecmua-i Ulum-i Riyaziye*, a four-volume-encyclopaedia that was published in 1831-1834, was credited for being the leading work that brought positive sciences like physics, chemistry, biology, astronomy, mathematics, pharmaceutics and zoology respectably to Ottoman State. In the work *Mecmua-i Ulum-i Riyaziye* which is mostly prepared with translation from Western sources, it is observed that adaptation was also applied.<sup>209</sup> The work, which gained so many new terms to Ottoman science terminology, was also the first book to

<sup>208</sup> İhsanoğlu, pp. 25-28.

<sup>209</sup> Hüseyin Gazi Topdemir, “Modern Fiziğin Türkiye’ye Girişinde Baş Hoca İshak Efendinin *Mecmû ‘a-i Ulûm-i Riyâziye* Adlı Çalışmasının Önemi”, Hasan Celal Güzel, Kemal Çiçek ve Salim Koca (ed.), *Türkler*, c. XVII, Ankara, 2002, pp. 897–905.

bring an article about chemistry to Ottoman Empire. Additionally, *Usul-i İstihkamat* published in 1832-34 was a work that Ishak Efendi translated from French and was related with new style military engineering. In 1832-1835 Ishak Efendi's *Aksü'l- Meraya fi Ahzi'z Zevaya*, a book that involves subjects like astronomy and mathematics, was published. Apart from those works, there are also pamphlets, named *Küre*, *Hikmet*, *Sekant* and manuscripts named *Kavaid-i Ressamiye*, *Risale-i Ceyb* and *El-Risalet el-Berkiyye*. From those, *Kavaid-i Ressamiye* is related with applications and regulations of chaining and *Risale-i Ceyb* is about the usage of an astronomy gadget that called Ceyb-i Afaki. Finally, *El-Risalet el-Berkiyye* which is also known as *Deniz Lağımı Risalesi* (Pamphlet of Sea Mine) is a translated book from French that refers to sea torpidos.<sup>210</sup>

### 4.3. Statements of Optics in Mecmua-i Ulum-i Riyaziye

The last three articles of Mecmua-i Ulum-i Riyaziye that are located in the 3<sup>rd</sup> volume of the book are about optics. The first one of them includes subjects like nature of light, features of light, transmission of light from a source, reflection and refraction of light and lastly formation of colours. The first article is separated into nine chapters. The first chapter refers to nature and the qualifications of light. The second chapter is about transmission of light from a source. The third and fourth chapters are dealing with the formation of shadow and thoughts and objections about transmission of light from a source. The last five chapters are respectively referring to; phosphoric objects, refraction of light, reflection of light, formation of colours and different features of beam's refraction.

The second article is separated into five chapters that refer mainly to the eye and vision. In the first chapter, the anatomy of eye is recited. The second and third chapters refer to the shapes and magnitudes of the visuals. The fourth chapter is about the images' distance to visible items and the last chapter is about images' motion.

Lastly in 3<sup>rd</sup> article, plane, concave and convex mirrors are mentioned and some gadgets are introduced. The article is separated into three chapters and the first chapter is about plane mirrors and the second chapter is about the concave and convex mirrors. In the third chapter, some gadgets, which are related with reflection and refraction, are mentioned.

---

<sup>210</sup> İhsanoğlu, pp.34-43.

The optical information in the last three articles of *Mecmua-i Ulum-i Riyaziye* is compatible with the optical information in Baron Reynaud's 1824-published-book, *Traite Elementaire de Mathématiques de Physique et de Chimie*. Also it is compatible with the optical information that resides in the “*De La lumière*” named part of the second volume of Reynaud's 1839-published-book, *Traite Elementaire de Mathématique et de Physique*.<sup>211</sup> In this work, Reynaud's “*De La lumière*” that was published in 1839 and the optics related articles of İshak Efendi's “*Mecmua-i Ulum-i Riyaziye* are examined together. It was tried to be understood which subjects were translated by İshak Efendi from the French work and what kind of terminology was being used. In Reynaud's work “*De La lumière*” the included subjects are respectively; direct light, reflected light, mirrors, refracting light, some effects of refracting light, colours, concave and convex lenses, biconcave and biconvex lenses, formation of vision, telescopes, combination and usage of microscopes. Concordantly, although there is a general parallelism between the subjects; it is seen that in treatment there are some subjects that Chief Instructor İshak Efendi preferably enlarges or minimizes during citation. Also it is seen that, instead of literally translating the optical information in the French work, İshak Efendi translated the work by internalizing the information and citing them in a simple and expositional way.

In the statements of optics in *Mecmua-i Ulum-i Riyaziye*, age's modern optics subjects, like “diffraction”, “interference” and “photoelectric”, weren't included. This shows that, according to Physical terms, the modern optics didn't enter to the Ottoman Empire with *Mecmua-i Ulum-i Riyaziye*.<sup>212</sup> There is a terminological difference of the usage of the word “modern” between science and history of science. In history of science, “modern” is used for the science developed beginning from the age of enlightenment, while in science it is used to describe post-Newtonian concepts of physics like quantum mechanics. As a result we continue to use the word “modern” in this work referring to scientific works after Newton. The importance of this work for the science of optics is that it provided same level of optics education with Ottoman engineer schools and western education institutions that source books of *Mecmua-i Ulum-i Riyaziye* were being used in universities in the west as well. Another importance of the work is that subjects related to

---

<sup>211</sup> İhsanoğlu, p.60.

<sup>212</sup> Hüseyin Gazi Topdemir, “Modern Fiziğin Türkiye'ye Girişinde Baş Hoca İshak Efendinin *Mecmû 'a-i Ulûm-i Riyâziye* Adlı Çalışmasının Önemi”, Hasan Celal Güzel, Kemal Çiçek ve Salim Koca (ed.), *Türkler*, c. XVII, Ankara, 2002, pp. 897–905.

optics were submitted respectably in the encyclopaedia which is credited for being the first encyclopaedic work including positive sciences in Ottoman State.

In this work, the first two articles of *Mecmua-i Ulum-i Riyaziye* are summarized and the third article is translated literally from Ottoman to English, without any simplification to show how *Mecmua-i Ulum-i Riyaziye* discusses the subjects. The figures that are used in the work are from the figure section which is the last section of *Mecmua-i Ulum-i Riyaziye*. Because of the linguistic differences in both languages, some sentences of the third article might be resulted in a complex form. It is aimed to increase the intelligibility of the work by replacing the Arabic letters that are used in explanations of the figures and texts, to Latin letters as in the table. Also, to assimilate the text with the figures, the Arabic letters that are used in original text are indicated between parentheses.

Table 4.1. Arabic letters versus Latin letters.

ا	A	س	L	ل	W
ب	B	ش	M	م	X
ث	C	ص	N	ن	Y
ت	D	ض	O	و	Z
ج	E	ط	P	ه	$\alpha$
ح	F	ظ	Q	ي	$\beta$
خ	G	ع	R	ء	$\gamma$
د	H	غ	S	٦	$\delta$
ذ	I	ف	T	٧	$\epsilon$
ر	J	ق	U		
ز	K	ك	V		

#### 4.3.1. The First Article about Features, Formation, Reflection, Refraction of Light and Formation of Colours

The introduction part of *Mecmua-i Ulum-i Riyaziye*'s first article that is related with optics begins with the definition of optics as a science subject and the definitions of luminous and illuminated objects. In this context, optics is defined as the information about the formation of vision that occurs via light. Luminous object is defined as the object that doesn't get light from other source but produces its own light and Sun is given as an example. On the other hand, illuminated object is defined as the object that doesn't

produce its own light but gets it from other sources which the Moon and other planets are given as examples. The introduction part continues with defining transparent object as the object penetrates light and gives air, water and glass as examples to it.<sup>213</sup> The source of light for both illuminated and luminous objects is defined as the illuminative object or illuminative point. The straight lines that reach out from the illuminative object to the illuminated object are called light beam. Also, the reversal of the beam from the illuminated object by not being able to penetrate the tissue of it is defined as reflection and the light that reverses is called as reflected light. It is stated that light is going to undergo refraction and deflection when transferring from one medium to another, like water to air or air to water, and the light that deflects from its direction is called refracted light. It is stated that while optics is used to refer to the arguments about direct light, the arguments of refracted light and the arguments of reflected light are dealt with under the name of refractive and reflective optics. However, since those three kinds of arguments are processed relatedly in practical terms they are all studied under the name of optics. It is stated in the article that optics is a practical science, thus the claims about it can be proven with experiments. Also, since it has a close relation with geometry it can be counted as an objective science. In the text, it's stated that among the former scholars' ideas about nature of light, its features, speed and elasticity, it was only dealt with the proven ideas not to cause a confusion.<sup>214</sup>

The first part is related with the basis and features of light. In this part light is claimed to be an object and this fact is tried to be proven. Four arguments are introduced in the text in order to prove this point; First the dazzling effect of light at the instant it reaches to the eye, secondly the reflection of the objects as if they were elastic when the light reaches the solid, thirdly the refraction of light between mediums that have different density and lastly the caustic form of sun light when it accumulates in the focal point of a convex lens. Light's enabling the formation of vision and having effects like reflection, refraction, etc. is explained in the text with light's feature of motivity. Also by mentioning the light's transmission between two places happening in a constant timeframe, it is tried to be proven that light isn't able to have an infinite speed.<sup>215</sup> The necessity of the reflection of light from the object reaching through the brain is explained for the formation of vision

---

<sup>213</sup> Hoca İshak Efendi, *Mecmua-i Ulum-i Riyaziye*, Amire Matbaası, Istanbul 1831, p. 460.

<sup>214</sup> Hoca İshak Efendi, p. 461.

<sup>215</sup> Hoca İshak Efendi, p. 462.

and it is defended that this would not be possible with light having infinite speed. The last argument defended about the light is that reflection doesn't change the speed of light and it's exemplified by claiming that light beam reflected from both Sun and from another object would have the same refractive features when they enter a place and this is possible only if they both have the same speed.<sup>216</sup>

The second part is about the origination and propagation of light. In this part, it is defended that light is originated in a spherical form and the centre of the sphere is the illuminative point. To support this idea, it is stated that if a candle is put in the middle of a room it can be seen from each part of the room since it propagates light to every direction of the room. So the candle must be taken as the illuminative point and the light rays propagated to the entire of the room will form a sphere that the candle is the centre of it. The Sun's illuminating other planets in its orbit is also shown as a proof for the sphere model and it is stated that there exists a sphere that Sun is the centre of it and the furthest planet that's illuminated from Sun forms the radius. Addition to that, it is stated that light would decline proportionally to the square of the distance it covered. It is evidenced that from the beams that propagate from a candle which is oriented in a specific place and reaches to surface of an illuminated object, a cone like Figure 4.1 is formed in which the candle is the top and the illuminated object is the base.<sup>217</sup>

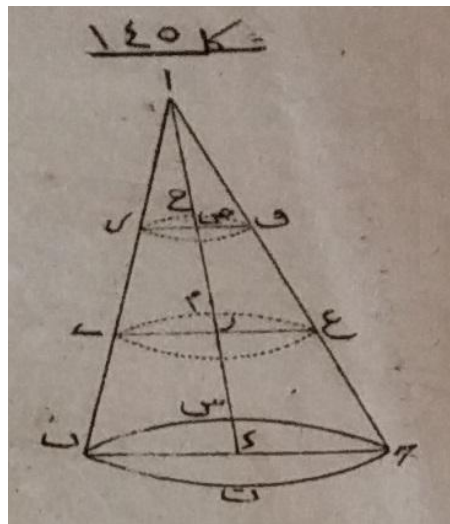


Figure 4.1. Formation of a visual cone.

<sup>216</sup> Hoca İshak Efendi, pp. 463-465.

<sup>217</sup> Hoca İshak Efendi, pp. 468-469.



enlightened with these four motions, the former philosophers concluded that light propagates from its source forming the shape of a cone. Also they claimed that the propagation of light from its source to the objects is like it's passing through little spheres that lined in a straight stick and that light has a vibration motion. However, later they concluded that light proceeds linearly but not curvedly like sound and that's why its propagation can't be explained with the vibration model. To refute this idea, it's stated in the text that when waves hit a barrier they propagate curvedly behind it, on the other hand, it is not possible for light to propagate that way. It's also mentioned that in order that light having an inclined motion, former philosophers claimed that universe has to be full with aether. And since aether causes a friction during light's refraction, they claimed that aether didn't exist and the universe was empty. This defence is one of the ideas that put forward in Mecmua-i Ulum-i Riyaziye's first article on optics. As a result, it's concluded that light's propagation accords with the transposition motion among the four other kinds of motion.<sup>221</sup>

The fifth part is about phosphoric objects. Phosphoric objects are defined as the objects that propagate light in dark and it is claimed that each object has its phosphoric elements. Yet, it is stated that electric current exists in each object and it's able to generate light in dark just like phosphoric objects. That's why it is mentioned that phosphoric objects are more relevant with the research area of Electrics rather than Optics but still it was briefly recited for the sake of natural course of research. As an example for phosphoric objects, the fireflies and some special kinds of insects that exist in Africa and Italy are given and it's stated that passengers can use those insects as a gadget for lightening in the dark by putting them in a box. A kind of crustacean sea insect that emit light and trees that propagate light when they become old, are among other examples. Also, the sparkles that occur on the sea when northeaster blows stated to be connected to the electric current that's created by the interaction of wind and sulphur present in sea waters.<sup>222</sup>

The sixth part is about the refraction of light. Firstly it is stated that light doesn't refract when it passes vertically and then refraction is attributed to two basic reasons. These are defined as the change of resistance of light when it passes through mediums with different densities and the differentiation of the effect of gravity on light in mediums with

---

<sup>221</sup> Hoca İshak Efendi, pp. 496-499.

<sup>222</sup> Hoca İshak Efendi, pp. 504-506.



intense medium. The third ground states that the ratio between the sines of the inclination angle and the refracting angle will remain constant during transition from one place to another. Lastly, the fourth ground is that light won't be refracted when it reaches vertically to the surface of the medium with different density.<sup>225</sup>

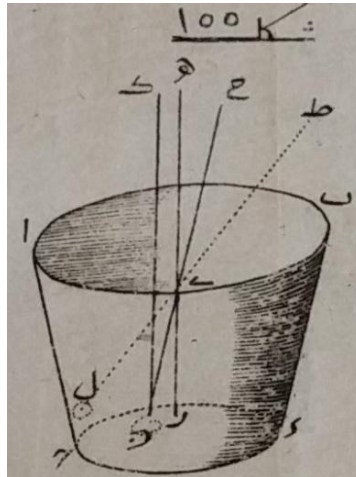


Figure 4.4. Transposition of the perceived location of an image due to refraction.

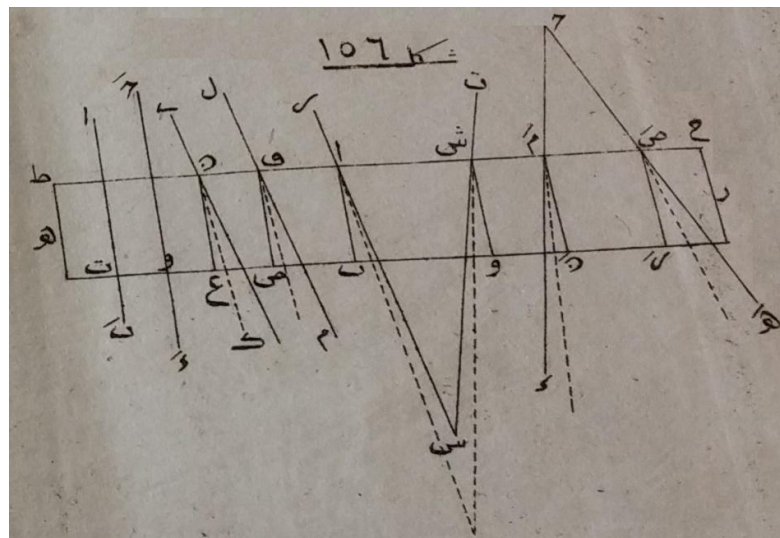


Figure 4.5. Parallel transmission of light from a glass.

Apart from these, in Figure 4.5, it is illustrated that the entering light beams to the glass will be parallel to the leaving light beams from the glass in three different cases

<sup>225</sup> Hoca İshak Efendi, pp. 520-522.



equal to the arc  $B\alpha$  (ب ه) and the incident angle  $\alpha V A$  (ا ك ه) would be equal to the angle of reflection  $\gamma V \delta$  (ه ك ٦).<sup>228</sup>

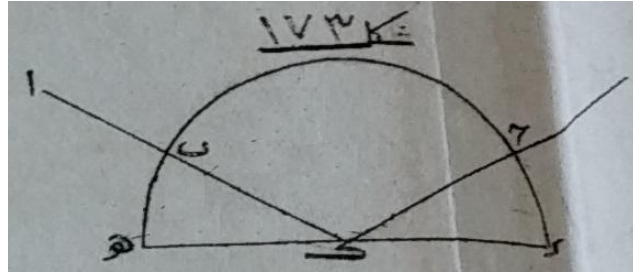


Figure 4.7. Incident and reflected angles.

The eighth part is about colours. As in the Figure 4.8, if a beam enters to a dark room from the hole  $B A$  (ب ا) in the window and passes through the triangular prism's surface  $\alpha \gamma \delta$  (ه ه ٦) the beam will reflect to the wall  $R U$  (ع ق) and seven colours will occur. It is stated that wall's point  $\alpha$  (ه) will be in red colour, the point  $L$  (س) will be orange,  $N$  (ص) will be yellow,  $T$  (ف) will be green,  $V$  (ك) will be blue,  $T'$  (ف) will be dark blue and  $\epsilon$  (ع) will be purple and that these colours are present in the light before it passes through the prism and refract. Also it's added that, separation into seven colours is a future of the white light and other coloured lights won't be separated but be reflected with their own colours.<sup>229</sup>

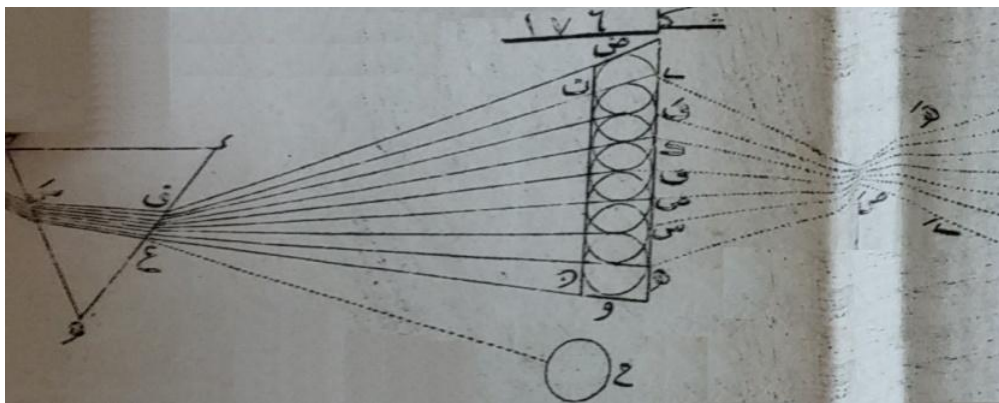


Figure 4.8. Separation of the white light into seven colours.

The ninth part is about the different features of the refraction of light and again emphasising that light which passes through the prism will be separated into seven basic

<sup>228</sup> Hoca İshak Efendi, pp. 543-544.

<sup>229</sup> Hoca İshak Efendi, p. 547.

colours. As it is seen in Figure 4.8, the lights are ranged from the least refracted to the most refracted one. While the red light's refraction rate is lesser than the orange, orange is lesser than the yellow and it is lesser than the green etc. If light's refraction features weren't like this, then they would pass through the prism parallel to each other and they would have to stay parallel after their departure from the mirror by creating equal angles on inclined surface  $\alpha F$  (ح °). It is concluded that this situation is opponent to the experience.<sup>230</sup>

#### 4.3.2. The Second Article about the Examination of the Eye and the Formation of the Vision and also the Shape, Quantity, Distance and Motion of the Visuals in Optics

In the second article, the introduction part mostly deals with the shape of the eye and it states that eye is a whole sphere which has a saliency forward. As it is shown in Figure 4.9 the external part  $\delta B F V \varepsilon P J \gamma Z$  (و ء ر ط ء ك ح ب ٦) of the eye has three layers which originally aren't exact circle however in the figure it is symbolically shown as circular lines. The biggest external layer,  $\delta F V \varepsilon P \gamma$  (ء ط ء ك ح ء) is called Cornea. Besides stating that cornea is a solid, intense sphere layer, it is also mentioned that its radius has a magnitude of seven bars according to the figure. In order for light beams to pass through this layer, the layer's forward side  $\gamma \delta B$  (ب ٦ ء) should be in a bright form and the rest should be in a white and non-luminous form. That's why the side  $\gamma \delta B$  (ب ٦ ء) is called as bright cornea and the rest is called solid cornea.

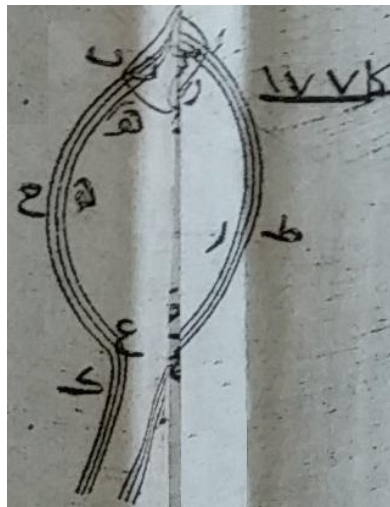


Figure 4.9. External layers of the eye.

<sup>230</sup> Hoca İshak Efendi, pp. 555-556.

Cornea also has a layer that its scale is smaller than cornea's and it is called as pupil layer. Cornea layer consists of two parts; B R  $\gamma$  (ب ع ء) part is choroid which exists at the behind and the fore part  $\gamma$  L C B (ب ت س ء) is pupil. It is stated that the circular hole that is seen inside the bright cornea when looking into someone's eye, is pupil and the part that includes the pupil is called iris.<sup>231</sup> Iris is covered with plenty of fibres in various colours. Due to those fibres, several movements of iris occur. To prevent light's access to the eye when it's in excess quantity, pupil narrows with circle fibres and the amount of light in the area decreases. On the other hand, when there is a need for more light, rectangle fibres enlarge the pupil.

Choroid's B  $\alpha$  P J  $\gamma$  (ب ر ط ه ء) part that involves the lens layer J P  $\alpha$  K (ز ه ط ر), which is going to be mentioned, is compromised of so many fibres like J  $\gamma$   $\alpha$  B (ب ه ء ر). Those fibres are divided into branches in the pupil layer and there exists the posterior chamber. It involves the convex surface J P  $\alpha$  (ز ه ط ر) of lens layer. And those fibres aren't transparent like pupil to prevent the beams that come curvedly through the eye at points J (ر),  $\alpha$  (ه). Another part of the eye is J J F  $\alpha$   $\alpha$  (ح ر ر) which is the third layer with a quite spherical form. This layer, that its diameter is smaller than the choroid's is called retina.<sup>232</sup> This layer lengthen the whole part J J F  $\alpha$   $\alpha$  (ح ر ر) and ends at pupil's corners  $\alpha$  (ه), J (ر). It is also mentioned that the layer is thicker inside of the eye and thinner at the other side. In order that light to reach the pupil from the spherical area A (ل) that is rounded with three layers, it has to pass through three mediums. The first medium is called as Aqueous humour, second one is Crystalline humour (lens) and the third one is Vitreous humour.

The Aqueous humour is in opaque form like albumen and it consists of two rooms, called front and back room. One of the rooms is between the  $\gamma$   $\delta$  B (ب ٦ ء) bright cornea and pupil  $\gamma$  L C B (ب ت س ء) and the other room is between the pupil P J K  $\alpha$  (ز ر ط) and lens. These rooms adjoin on the pupil hole. After Aqueous humour, it is stated that the lens P J K  $\alpha$  (ز ر ط) which consists of a very thick layer and resembles a crystal glass. Lens' form is round and convex on the front and it resides in the middle of the eye. It is stated that lens' length, space and curvature changes person to person and especially it gets thicker in time. Vitreous humour is a glass-like transparent element that is thicker than Aqueous humour and resides in the third room J A  $\alpha$  (ح ر ر). This room covers the most of the internal parts of eye and it's separated from the lens with the convex circle J P  $\alpha$  (ز ه ط ر)

<sup>231</sup> Hoca İshak Efendi, p. 562.

<sup>232</sup> Hoca İshak Efendi, pp. 563.

and it's separated from the Aqueous humour  $J \alpha' (\text{ج } \alpha')$  with the posterior chamber. This room ends at the behind part of the eye where exists the visual nerves that reach to the brain.<sup>233</sup> Also these nerves consist of three separate layers; one of them is the external layer sclerotic tissue and the one under it is the optic nerves. The last layer is retinal vessels. It's the internal layer which approaches to the visual cortex and which consists of brain's  $\epsilon P \delta V Z$  ( $\epsilon \text{ و } \delta \text{ و } \text{ك } \text{ط } \text{ع}$ ) part, cornea layer, sclerotic tissue and choroid. It is also stated that there are two round holes on the two side of the forehead to transmit each branches of the visual nerves to the eye and this area is called as orbit of the eye. Besides, there are four smooth muscles in eye that provides the motion and one of those makes eye move up to down, the other makes down to up and the third muscle approaches nose while the fourth muscle pulls the eye away from nose. As eyelids preserve the eye from all the external damages, it also blocks the entrance of over light. There are two glands on the sides of the both eyes that is called lachrymal gland to prevent the eyes with lachrymation from the damages that might happen due to the friction during the eyelids opening and closing. It is also stated in the text that those glands can send the lacrima outside of the eye by being squeezed with the motions of the eyelids. There are also a line of hairs on the eyelids' round corners that are called eyelashes, in order to provide the eye from flying objects. The eyelashes that exist in the upper eyelid are curved upward and the ones on the lower eyelid curves downward not to block the light entrance.<sup>234</sup>

The first chapter, which follows the beginning part of *Mecmua-i Ulum-i Riyaziye*'s second article, is about the formation of vision. Firstly the part starts with stating that each bright point is seen via a pair of cone of vision. While the cones' base is on pupil, one of their top is on the illuminated point and the other top is on the lens layer. As in the Figure 4.10, the illuminated point  $\gamma (\epsilon)$  can be seen by a double cone of vision  $P J \alpha \gamma$  ( $\text{ط } \text{ج } \alpha \text{ و } \epsilon$ ) and the top of the larger cone  $J \alpha \gamma$  ( $\text{ج } \alpha \text{ و } \epsilon$ ) would be on the point  $\gamma (\epsilon)$  and the base  $J \alpha Z$  ( $\text{ج } \alpha \text{ و } \text{و}$ ) would be on the pupil. The minor cone  $P J \alpha Z$  ( $\text{ط } \text{ج } \alpha \text{ و } \text{و}$ )'s top would be on the point  $P$  ( $\text{ط}$ ) and the common base  $J \alpha Z$  ( $\text{ج } \alpha \text{ و } \text{و}$ ) would be on the pupil.

<sup>233</sup> Hoca İshak Efendi, pp. 564.

<sup>234</sup> Hoca İshak Efendi, pp. 565-566.

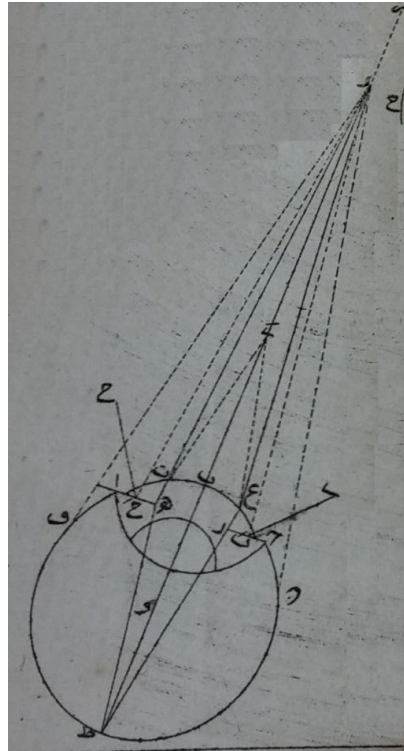


Figure 4.10. Visual perception using a double cone of vision.

Yet from the light rays emerging from the illuminated point as spheres if the ones emanated to the  $P \delta B A$  ( $\text{ط ب ا}$ ) external circle of the eye were disregarded and the rays existing in the external circle were considered only, it would be clear that the rays  $B \gamma$  ( $\text{ب ء}$ ),  $K \gamma$  ( $\text{ك ء}$ ), are present in the sclera of the eye. The sclera of the eye is able to reflect light and so it would become a visible part of the eye for other people. Also it is stated that, some of the beams would enter the eye after passing the  $\delta B A$  ( $\text{ب ا}$ ) cornea, in which they are going to get closer and be refracted. Some other beams would enter the pupil like  $F' \gamma$  ( $\text{ف' ء}$ ),  $B' \gamma$  ( $\text{ب' ء}$ ) beams, which enter the pupil from left and right as it is shown in the figure, and be reflected from the pupil and go towards the  $F F'$  ( $\text{ح ء}$ ),  $B' \epsilon$  ( $\text{ب' ؤ}$ ) directions.<sup>235</sup>

Some of the beams that weren't reflected enter the eye and reach the pupil without refraction, like the beams  $\alpha \gamma$  ( $\text{ا ء}$ ),  $J \gamma$  ( $\text{ج ء}$ ). A great amount of light beam is required to reach the point  $P$  ( $\text{ط}$ ) which is a lens layer's restricted part. Beams that are reflected from point  $\gamma$  ( $\text{ء}$ ), head the points right and left of  $P$  ( $\text{ط}$ )'s. Most of the points that beams reach, surround the point  $P$  ( $\text{ط}$ ) and won't be able to reach till the brain. So the gathering of the

<sup>235</sup> Hoca İshak Efendi, p. 567.

lens layer's beams, which propagate from point  $\gamma$  ( $\epsilon$ ) and enter the pupil, altogether at point P ( $\zeta$ ) only happens by the mentioned points.

The beam P B  $\gamma$  ( $\zeta$   $\beta$   $\epsilon$ ) is the only beam that reaches the point P ( $\zeta$ ) among the whole other beams that are reflected from the point  $\gamma$  ( $\epsilon$ ) through the cornea layer  $\delta$  B A ( $\tau$   $\beta$   $\lambda$ ), and this beam is called as visual cortex. These beams aren't refracted for their vertical incidence onto the surfaces of the intermediate mediums. The beams  $\alpha$   $\gamma$  ( $\sigma$   $\epsilon$ ), J  $\gamma$  ( $\iota$   $\epsilon$ ) and others can't reach up to the point P ( $\zeta$ ) because of their scattering after refraction. It is stated that from these beams, a cone, of which diameter is line J  $\alpha$  ( $\iota$   $\sigma$ ) and peak is point P ( $\zeta$ ), is formed. In the text, the vision of the illuminated point  $\gamma$  ( $\epsilon$ ) with a double vision cone is described this way.<sup>236</sup> Besides, it is stated that the objects' distance of easy visibility is not equal at every people. Among the two people, ones cornea layer can be more transparent than the other or Aqueous humour can be more curved, hence the refraction that occurs in the eye of one of them can be further than the other one's and light can progress more distance to gather on the lens. The text continues on vision disorders with the given example below. That if someone's eye's curve is capable to read a writing from B  $\gamma$  ( $\beta$   $\epsilon$ ) distance, which is considered as equal to nine units, and someone else's eyes are supposed to be more curved and positioned towards the B  $\gamma$  ( $\beta$   $\epsilon$ ), beams would be refracted and intersect before the point P ( $\zeta$ ). That's why the writing to read should be put to B  $\epsilon$  ( $\beta$   $\zeta$ ) point, of which distance is lesser than nine units. For an old man, whose eyes are weaker, C  $\gamma$  ( $\tau$   $\epsilon$ ) should be nearer than the point R  $\gamma$  ( $\xi$   $\epsilon$ ) distance for his lens to collect the refracted beams at P ( $\zeta$ ) point because in his eyes light will be refracted lesser. Thus, someone who cannot see the further is called weak sighted.<sup>237</sup>

Second part is related with shapes of the objects. In the beginning of the part it is stated that an object that is located not just in one point but originates from points located in different places, can be seen by using two pyramids. While one of the pyramids' bases would be on object, the other one's would be on the retina of the observer's eye and both of their peaks would be on the pupil. As it is seen in the Figure 4.11, triangle  $\delta$  B A ( $\tau$   $\beta$   $\lambda$ ) can be seen due to two triangular pyramids  $\gamma$   $\delta$  B A ( $\epsilon$   $\tau$   $\beta$   $\lambda$ ) and  $\gamma$   $\delta$  B' A' ( $\epsilon$   $\tau$   $\beta$   $\lambda$ ). Also it is stated that while one of the pyramids' base  $\delta$  B A ( $\tau$   $\beta$   $\lambda$ ) would be on the object the other base  $\delta$  B' A' ( $\tau$   $\beta$   $\lambda$ ) would be on the lens and both of their peak points  $\gamma$  ( $\epsilon$ ) would be on the pupil.

<sup>236</sup> Hoca İshak Efendi, p. 568.

<sup>237</sup> Hoca İshak Efendi, pp. 573-574.

It is stated that, point A (ل) can be seen by cone  $A' \gamma A$  (ل ء ل), point B (ب) can be seen by cone  $B' \gamma B$  (ب ء ب) and point  $\delta$  (٦) can be seen by cone  $\delta' \gamma \delta$  (٦ ء ٦). Also, because of the fact that triangle  $\delta B A$  (٦ ب ل)'s area is wider than pupil  $\gamma$  (ء)'s eye, triangle pyramid  $\gamma \delta B A$  (ء ٦ ب ل) is formed in case of beams  $\gamma A$  (ء ل),  $\gamma B$  (ء ب),  $\gamma \delta$  (ء ٦) don't intersect and reach the pupil  $\gamma$  (ء). This triangle's base would be on triangle  $\delta B A$  (٦ ب ل) and its peak point  $\gamma$  (ء) would be on the pupil. The mentioned three beams;  $\gamma A$  (ء ل),  $\gamma B$  (ء ب),  $\gamma \delta$  (ء ٦) would move away curvedly after they intersect on point  $\gamma$  (ء). While the lens tried to be on points  $\delta$  (٦), B (ب), A (ل), both the points  $\delta$  (٦), B (ب), A (ل) and points  $\delta'$  (٦'), B' (ب'), A' (ل'), both the points  $\delta'$  (٦'), B' (ب'), A' (ل') won't be in the same direction between each other and a different triangle  $\delta' B' A'$  (٦' ب' ل') would become on the retina. With the collection of beams  $A' \gamma$  (ل ء),  $B' \gamma$  (ب ء),  $\delta' \gamma$  (٦ ء), a new triangular pyramid  $\delta' B' A' \gamma$  (٦' ب' ل' ء) would be formed and this triangle's base  $\delta' B' A'$  (٦' ب' ل') would be on the lens and the peak point would be on the pupil  $\gamma$  (ء).

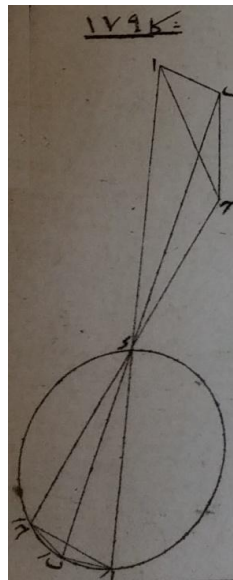


Figure 4.11. Visual perception using two triangular pyramids

As a conclusion, with the joining of three straight lines  $\gamma A$  (ء ل),  $\gamma B$  (ء ب),  $\gamma \delta$  (ء ٦) on triangle  $\delta B A$  (٦ ب ل)'s three points, if we consider that each light beams which come from the all visible points of triangle  $\delta B A$  (٦ ب ل), is lined as denominator from point  $\gamma$  (ء) two beam pyramid  $\gamma \delta B A$  (ء ٦ ب ل),  $\gamma \delta' B' A'$  (ء ٦' ب' ل') would be formed. Also due to them, triangle  $\delta B A$  (٦ ب ل) would be observed, and one's base would be on the object  $\delta B A$  (٦ ب ل) and the other's is on the retina and the mutual peak point would be on the pupil  $\gamma$  (ء).<sup>238</sup>

<sup>238</sup> Hoca İshak Efendi, pp. 576-578.

Finally in the second part, it is stated that the area on the lens layer which occurs to be collided and stimulated with the light beams emerging from each point of the triangular, is called the “visible” (object). Hence, the image of the triangle  $\delta B A (\bar{\nu} \beta \lambda)$  would be the triangle  $\delta \bar{B} \bar{A} (\bar{\nu} \beta \lambda)$ .<sup>239</sup>

The third part is about the size of the objects. The part is started with the information that the size of the object can be estimated by the angle which is formed by the beams that propagate from both sides of the object.

In Figure 4.12 it is showed that the size of the straight line  $\delta A (\bar{\nu} \lambda)$ , which is the length between an object's endpoints, can be measured with the angle  $\delta \gamma A (\bar{\nu} \epsilon \lambda)$  that is formed by beams  $\gamma \delta (\epsilon \bar{\nu})$  and  $\gamma A (\epsilon \lambda)$  which propagate from the line  $\delta A (\bar{\nu} \lambda)$ 's corners  $\delta (\bar{\nu})$  and  $A (\lambda)$ . Hence, it is stated that the size of the line  $\delta A (\bar{\nu} \lambda)$  can be measured visibly on the retina by the beams that propagate from it and by using object  $\delta \bar{A} (\bar{\nu} \lambda)$ 's length. Since the triangles  $\gamma \delta A (\epsilon \bar{\nu} \lambda)$ ,  $\gamma \delta \bar{A} (\epsilon \bar{\nu} \lambda)$  are combined and the angle  $\gamma (\epsilon)$  is common, the legs  $\delta A (\bar{\nu} \lambda)$ ,  $\delta \bar{A} (\bar{\nu} \lambda)$  would be similar.

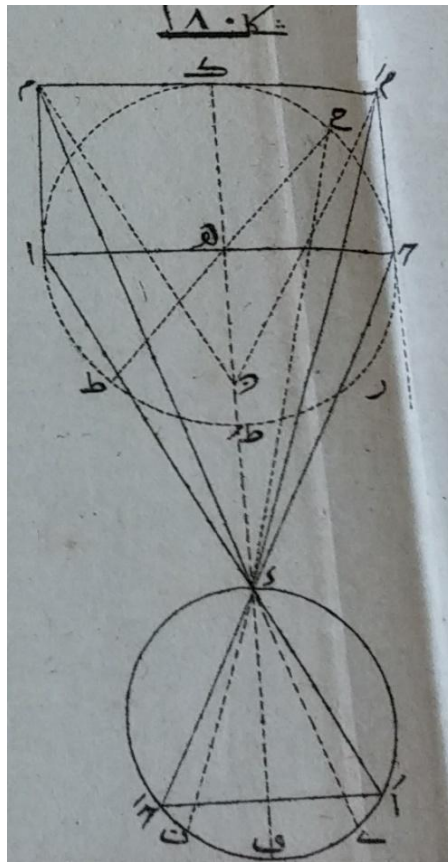


Figure 4.12. Determination of the size of an image using a two-pyramid system

<sup>239</sup> Hoca İshak Efendi, p. 578.

Thus, when the angle  $\delta \gamma A' (\epsilon \tau')$  gets wider the angle  $\delta A (\tau')$  would get wider, and when the edge gets bigger, also edge  $\delta A' (\tau')$  would also get bigger. Also as the angle  $\delta \gamma A (\tau \epsilon')$  gets wider, retina's length  $\delta A (\tau')$  that is stimulated by the beams which propagate from the leg  $(\tau')$ , would also shows bigger. It is defined in the text that the object  $\delta A (\tau')$ 's size can be measured with the size of the angle  $\delta \gamma A (\tau \epsilon')$ .<sup>240</sup>

As in the Figure 4.13, the rate of the object  $FJ (\zeta \nu)$  to the object  $\gamma A (\epsilon')$  would be equal to the rate of the object's distance  $RF (\xi \zeta)$  to the pupil and pupil's distance  $AR (l \xi)$  to lens.

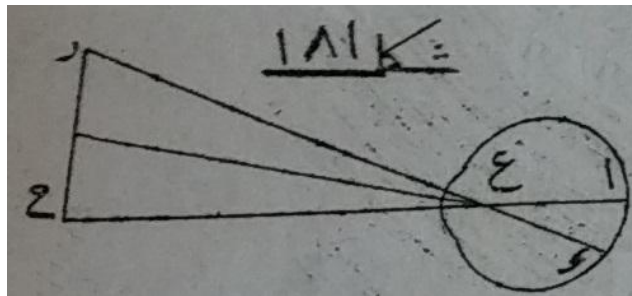


Figure 4.13. Equivalent ratios in the formation of vision.

Yet,  $RJ (\xi \nu)$  lights coming out of the visible  $FJ (\zeta \nu)$  and  $FR (\zeta \xi)$  lights of the  $R$   $F (\xi \zeta)$  rays will be perpendicular to the  $FJ (\zeta \nu)$  visible. The refraction of the  $RZ (\xi \nu)$ ,  $\gamma RA (\epsilon \xi')$  lights will be quite a little because of the parallelism between the visible objects and the  $FJ (\zeta \nu)$  line which is also parallel to the eye. For this reason  $RF (\xi \zeta)$ ,  $AR (l \xi)$  and  $RJ (\xi \nu)$ ,  $\gamma R (\epsilon \xi')$  can be taken as straight lines and thus  $FRJ (\zeta \xi \nu)$ ,  $\gamma RA (\epsilon \xi')$  triangles will be taken as similar triangles. In that case it would be;

$$FJ (\zeta \nu) : \gamma A (\epsilon') = RF (\xi \zeta) : AR (l \xi)$$

Thus, it is stated that the visible object is parallel to the eye and in case of knowing any two of the angle, size and distance the third can be found.<sup>241</sup>

The fourth part is about the images' distance to objects. It states that this distance will be determined by the objects that are between the visible item and the eye. As an example, since there is a great distance between an observer's eye and the Sun, it might be presumed that Sun's position on the horizon is nearer than its position during the noon. Other examples that are given are that the assumption of the distances of the sun and other objects as they were at the end of a Telescope while stargazing; fire's closer appearance during the night compared to during the morning and despite their distance stars'

<sup>240</sup> Hoca İshak Efendi, p. 580.

<sup>241</sup> Hoca İshak Efendi, pp. 580-581.

appearance in the hole of a sphere which's centre is the eye. The moon, which is close to the earth and the stars that are far comparing the moon, would be seen in the same distance since there isn't any other object between them is another given example. As a conclusion, it is stated during the fourth part that each object's distance is determined according to the distances of other objects between the eye and itself. It is mentioned that a light beam will get weaker as its distance increases and that intense light would seem nearer than weak light. Painters' using shadowing using dull colours while drawing is connected with this reason that eye perceives light colours as they are farther.<sup>242</sup>

The fifth part is about the motions of the visible objects. In this part, it is stated that an object's motion is perceived with its image's motion occurring at lens. If the image is mobile and the observer is steady or vice versa in both cases it would be seen as it's moving. Firstly, in Figure 4.11, if it is assumed that the eye  $A\delta\gamma(\lambda\tau\epsilon)$  is steady and the object  $\delta A(\tau\lambda)$  is moving from right to left, the image of the object  $A\delta(\lambda\tau)$  would move from left to right and the point  $A(\lambda)$  would refer to the end of the edge of the line  $A\gamma A(\lambda\epsilon)$ . When the point  $A(\lambda)$  is actuated in the right side of the lens, the image  $A\delta(\lambda\tau)$  would move from right to left on the retina and the image  $\delta A(\tau\lambda)$  would seem completely opposite (right to left) to its own direction. That's the reason why when the retina moves from right to left, the image would be seen left to right. Secondly, when the object  $\delta A(\tau\lambda)$  is steady and the eye is moving, it would be seen as it's moving. There are two examples in the text about this feature of the objects. First, a person who is sitting would see the objects around him, moving in a circle orbit by turning his eye with a finger. The second one is a person who sits on a moving ship would assume the objects at the seaside are moving and this is connected with the fact that observer's eye's mobility is adjoint to the ship's mobility.<sup>243</sup>

Finally, when the motions of both the observer and the object are adjoint the observer only attributes one of the motions to the object. Another example in this field is when a person who is sitting in a fast moving ship looks at another person who is also sitting in the ship, the first one would see the second steady, additionally when the first one starts walking the second will see him moving. Both of the people wouldn't feel the fast movement of the ship. Secondly, when a person who is on the ship sticks a knife in an apple and throws the apple with knife vertically to the air, he would see that apple is falling.

<sup>242</sup> Hoca İshak Efendi, pp. 595-595.

<sup>243</sup> Hoca İshak Efendi, pp. 597-599.

The apple would move in a motion that combines vertical and horizontal motions of the apple, during its rise and fall. Meanwhile a person who watches from the seaside would observe the apple as it's following an orbit curved to the horizontal during its rise and fall, however the person who throws the apple can't observe the curvedly movement of the apple. Hence the horizontal movement is not common between the person and the apple and only the vertical movement of the apple would be observed. Thirdly, according to the ones, who believe that in 24 hours earth circulates from west to east and the Sun and other planets circulate from east to west, a nest of a bird that is built on a certain height, would cover a 9000 parasang distance during 24 hours. If the nest that is mentioned takes a distance of 98 parasang when the bird leaves it and if the bird covers a distance of 100 fathoms, the bird will arrive the nest exactly the same distance without taking into consideration of nest's 98 parasang removal. This is because when the bird leaves the nest, the 98 parasang distances that nest covers is also covered by the bird. When the bird flies back to the nest it won't feel this distance. Consequently, if three objects circulate around a point in different speeds and distances, an eye that is placed on one of the objects would observe the other ones sometimes mobile, sometimes rotating and other times steady. That's why when a person, who observes other planets from the Earth during their movement around the Sun from west to east, would see the planets on the opposite direction. The last part of the second article is completed with the statement of the fact that while measuring the distance and orbit of other planets, the earth's movement should also be taken into consideration and this information is mentioned in articles that are related with astronomy in *Mecmua-i Ulum-i Riyaziye*.<sup>244</sup>

#### **4.3.3. Third article about the conditions of reflection and deflection by flat and concave and convex mirrors**

Beginning;

An object which reflects the emitted rays respectively and in which its image is seen, is called flat mirror and this definition is the fundamental of the upcoming conditions. The first condition of an object to be a flat mirror is that firstly the reflected rays preserves their previous order and positions before the reflection. Yet, the lens of the eye stops the

---

<sup>244</sup> Hoca İshak Efendi, pp. 605-607.



the form the image will occur. The purpose of these statements is that every object being hollow cannot be taken apart from the total. According to the fourth condition; an object cannot be defined as a transparent mirror if the eye while looking at it cannot see the object. When the eye AB (اب) looks at the image  $\alpha$  (ا) from the mirror JP (ط), it cannot see the image  $\gamma$  (ع) with the ray which originates from the object  $\alpha$  (ا) comes through the mirror JP (ط) being reflected from F (ح). Still water is capable of being a mirror with having a flat and shiny surface.<sup>246</sup> For example, trees and during night stars are reflected to the water, the eye looks at the water and observes them without realizing their depth. Hence, crystal mirrors are named according to their compounds as flat, concave and convex mirrors.

### First Part is on Flat Mirrors

The issue of vision: Every illuminated point can be seen by a right cone. The vertical axis of the right cone is equal to the reflection axis. For example, (Figure 4.14) in the mirror PJ (ط) the illuminated point  $\gamma$  (ع) can be seen via the right cone  $\alpha$  B A (ابا). The mentioned cone's axis  $\alpha$  C (ات) will be equal to the refracted cone's  $\gamma$  R B A (ع ر ب ا) axis  $\gamma$  R C (ع ر ت). When the eye is in the position R (ع) of the mirror, it sees the image  $\gamma$  (ع), at the end  $\gamma$  (ع) of the axis R (ع) where the rays  $\gamma$   $\delta$  (ع ٦) and  $\gamma$  L (ع س) unites. Now the eye R (ع), instead of looking at the image from the direction  $\gamma$  R (ع ر) but looking from the direction  $\alpha$  R (ا ر), it sees the image  $\gamma$  (ع) in the point  $\alpha$  (ا). With the condition of  $\gamma$  R (ع ر) =  $\alpha$  R (ا ر), the eye is not in the point R (ع) but in the point C (ت). The image  $\gamma$  (ع) is seen at the end of the line  $\alpha$  R (ا ر) + R C (ع ت), in other words it is seen at the end of the axis  $\alpha$  R C (ا ر ت) of the right cone  $\alpha$  B A (ابا) which is equal to the diffracted cone  $\gamma$  R B A (ع ر ب ا). As a result the claim is proved.

Conclusion, the visual axis  $\alpha$  R C (ا ر ت) is the summation of the distances of the ray R  $\gamma$  (ع ر) and C R (ت ر), is equal to the distance created by the reflected ray which comes to the eye B A (ابا) from the point  $\gamma$  (ع).<sup>247</sup>

Conclusion; the distance of the image B A (ابا) to the mirror T R (ف ر) becomes equal to the distance of the image  $\alpha$  (ا) to the mirror. Because in the triangle  $\gamma$  R  $\alpha$  (ع ر ا), the vertical edges  $\gamma$  R (ع ر) and  $\alpha$  R (ا ر) are equal under the influence of the mirror and becomes an isosceles triangle. The incident angle and the reflection angle become equal. Because the T R (ف ر) surface of the mirror is orthogonal to the line  $\gamma$   $\alpha$  (ع ا), the condition  $\gamma$  T (ع ف) =  $\alpha$  T (ا ف) is satisfied. In the point  $\alpha$  (ا) where the image  $\gamma$  (ع) is seen, the

<sup>246</sup> Hoca İshak Efendi, p. 609.

<sup>247</sup> Hoca İshak Efendi, p. 610.



if a ray  $F A$  ( $\alpha$ ) comes from the top of the height  $A$  ( $\beta$ ) to the mirror  $J F$  ( $\gamma$ ) placed on the ground, it will be reflected to the observer  $R$  ( $\delta$ ). When a normal  $\alpha R$  ( $\epsilon$ ) is drawn from the point  $R$  ( $\delta$ ) to the ground, in the triangle  $\alpha F R$  ( $\zeta$ ) and  $B F A$  ( $\eta$ ), the angles  $B F A$  ( $\eta$ ) and  $\alpha F R$  ( $\zeta$ ) will be equal to each other. Also the remaining two angles will be equal too. Therefore these two triangles will be similar;

$$F \alpha (\zeta) : R \alpha (\epsilon) = B F (\eta) : AB (\beta)$$

and if the sides  $F \alpha$  ( $\zeta$ ),  $R \alpha$  ( $\epsilon$ ),  $B F$  ( $\eta$ ) are known, the length  $A B$  ( $\beta$ ) can also be found. It is required to come closer to the mirror till the height of the top of  $A$  ( $\beta$ ) can be seen in the mirror. Conclusion, if the mirror  $J P$  ( $\theta$ ) is parallel to the ground (Figure 4.14), the observer  $T \gamma$  ( $\iota$ ) is seen in the mirror upside down. As follows, its legs is on the point  $T$  ( $\iota$ ) of the mirror surface and head is on the point  $\alpha$  ( $\kappa$ ) of the mirror and its distance from the surface of the mirror is equal to the distance from the beyond of the mirror. Conclusion, mostly when one looks at the mirror, two images can be seen<sup>249</sup>, one is from the ray reflected from the outer surface of the mirror and other one is from the virtual surface at the back. In the beginning this image is poor. The ray reflected from the upper part of the mirror surface is weaker and closer than the ray reflected from the down part of the mirror, because the distance of the upper part is less than the distance of the down part. By saying mostly means that, firstly because of the visual axis  $\alpha R C$  ( $\lambda$ ) is orthogonal to the surface  $P J$  ( $\theta$ ) and because of the crystal is thin, there will only be one image. Since one of the images exists in front of the other image and these two images are quite close to each other, observer cannot notice them. Conclusion, in the mirror more the axis  $\gamma R C$  ( $\mu$ ) =  $\alpha R C$  ( $\lambda$ ) extends, more the image shortens. Each point of the image is seen closer to the end of the visual axis  $\alpha R C$  ( $\lambda$ ). When the image is in the point  $\gamma$  ( $\mu$ ), the size of the image will be in the point  $\alpha$  ( $\kappa$ ) which is the length of the axis with a distance  $\alpha R C$  ( $\lambda$ ). Whereas the distance increases, the size of the image shortens. The image  $\gamma$  ( $\mu$ ) in the mirror can be seen smaller whereas the visual axis  $\alpha R C$  ( $\lambda$ ) greatens. In other words it can be said that the size of the image in the mirror is equivalent to the visual axis  $\alpha R C$  ( $\lambda$ ).

Conclusion, if an object  $B A$  ( $\nu$ ) is positioned in between two equal mirrors, there will be many images in the mirror  $A$  ( $\beta$ ), the ones closer to the surface of the mirror will be bigger and easily visible since their existence is due to rays reflected from the image and

<sup>249</sup> Hoca İshak Efendi, p. 612.

mirror coming to the eye<sup>250</sup>. Now, the image extended in the mirror B (ب), can be seen in the mirror A (ا). The visual axis compared to the first image is the direction in the mirror where it comes from the image to the eye. Compared to the second image, in order light to be transferred firstly from the image to the mirror B (ب), secondly from the mirror B (ب) to the mirror A (ا) and thirdly from the mirror A (ا) to the eye, gathering of the rays occur in the same direction. For this reason, firstly, second image is seen beyond the first image and secondly the image is poorer and smaller. With of the spread of the first image seen in the mirror A (ا), inside the mirror B (ب), compared to the mirror A (ا) the new image occurs at the back of the second image. Its rays cover a longer distance than the second image and are weaker and smaller than the second image. Because of the successive reflection of the rays, each of these images in the other mirror exist till they become weaker and they intercept the distance the light travels, as a result a clear image does not occur in the lens of the eye.

Conclusion, the aforementioned mirrors are not parallel. If an angle occurs between them, an image occurs from among every two visible of the image, from the visible to each of the mirrors or from the ghost images occurring in each of the mirrors. Because of the condition mentioned above, images occurring in one mirror will occur in the other mirrors too.

Conclusion, if the  $V \varepsilon$  (ك ے) distance of the image in front of the mirror P J (ط ج) is parallel to the mirror's surface P J (ط ج) and if the eye's distance  $\gamma$  (ء) from the mirror is equal to the distance of the image  $V \varepsilon$  (ك ے), the rays  $Z \varepsilon$  (و ے) and  $L V$  (ك س) coming from the mentioned length's  $V \varepsilon$  (ك ے)<sup>251</sup> end parts and reflecting from the mirror will occur in the pupil  $\gamma$  (ء). The part  $L Z$  (و س) which is on the mirror becomes the half of the length  $V \varepsilon$  (ك ے). Since the eye  $\gamma$  (ء) sees the image  $V \varepsilon$  (ك ے) via the pyramid or via  $\gamma R V$   $\varepsilon$  (ء ك ع) refracted triangles and pyramids or via only  $\alpha V \varepsilon$  (ء ك ے) triangular. Also with the assumption that  $V \varepsilon$  (ك ے) and  $LZ$  (و س) lines are assumed to be parallel  $\alpha LZ$  (و س ے) and  $\alpha V \varepsilon$  (ء ك ے) would be similar triangles;

$$\alpha V \varepsilon (ء ك ے) = \alpha L (ء س) = V \varepsilon (ك ے) : LZ (و س)$$

<sup>250</sup> Hoca İshak Efendi, p. 613.

<sup>251</sup> Hoca İshak Efendi, p. 614.

then as in the triangles  $\alpha \gamma V$  (ك ء ه) and  $\alpha Z L$  (س و ه), the equalities will be  $\alpha Z$  (و ه) =  $\frac{1}{2} \alpha \gamma$  (ء ه) the equalities  $\alpha L$  (س و) =  $\frac{1}{2} \alpha V$  (ك ء ه) and  $L Z$  (س و) =  $\frac{1}{2} V \epsilon$  (ك ء ه) will also be established.

Conclusion; if a person stands perpendicular to the horizontal, and if the distance of the observer and the image from the mirror is equal, and if the length of the image is parallel to the surface of the mirror, then the image of the height of the person and the occupied part of the mirror are the half of that person. In order of the whole height of that person to be seen in the mirror, the length of the mirror must be at least half of that person.

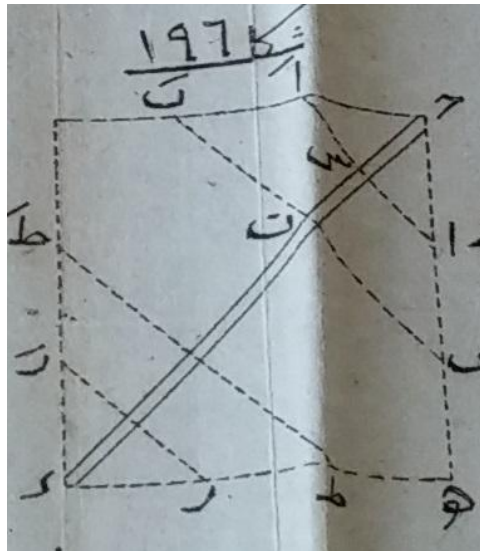


Figure 4.16. Formation of vision on an inclined mirror.

Conclusion; on the mirror  $\gamma F$  (ء ح) in Figure 4.16; if the straight line  $\alpha \gamma$  (ء ه) has a slope of 5 degrees difference, the perpendicular image is seen parallel and the parallel image is seen perpendicular. Namely, if the length  $B A$  (ب ا) is placed perpendicular to the surface  $\gamma F$  (ء ح), the mirrors  $A' L A$  (ا س ا) and  $B' C B$  (ب ت ب) are placed perpendicular, and if  $A' L$  (ا س) =  $A L$  (ا س) and  $B' C$  (ب ت) =  $B C$  (ب ت) are satisfied, then the  $A$  (ا) end of the line  $B A$  (ب ا) would be in the point  $A'$  (ا) and  $B$  (ب) end of the line  $B A$  (ب ا) would be in the point  $B'$  (ب). Also the image  $A' B'$  (ا ب) would be parallel to the horizontal  $\alpha \gamma$  (ء ه). In the triangles  $A L F$  (ا س ح) and  $\alpha \gamma F$  (ء ه ح), the angles  $\alpha$  (ء),  $L$  (س) are right angles. Since the angle  $F$  (ح)<sup>252</sup> is common, the triangles are similar. The angle  $\gamma$  (ء) is 45 degrees. Even in the

<sup>252</sup> Hoca İshak Efendi, p. 615.

triangle  $\alpha \gamma F$  ( $\circ \epsilon \zeta$ ), the angle  $F$  ( $\zeta$ ) is equal to 45 degrees. The angles  $\gamma$  ( $\epsilon$ ),  $F$  ( $\zeta$ ) of the triangles  $A L F$  ( $\text{ا س ا}$ ) and  $\alpha \gamma F$  ( $\circ \epsilon \zeta$ ) are equal to 45 degrees as well. And furthermore the triangles  $A L F$  ( $\text{ا س ا}$ ) and  $L A' F$  ( $\text{ا س ا}$ ) are equal. Since the side  $A' A$  ( $\text{ا ا}$ ) is split into half by the right side  $A' A$  ( $\text{ا ا}$ ), the triangle  $A' A F$  ( $\text{ا ا ا}$ ) becomes an isosceles triangle and because the sides  $A F$  ( $\text{ا ا}$ ) and  $A' F$  ( $\text{ا ا}$ ) are equal right sides, the angles facing these sides becomes equal. The angles  $A' A$  ( $\text{ا ا}$ ) of the triangle  $A' A F$  ( $\text{ا ا ا}$ ) becomes 45 degrees and the third angle  $A F A'$  ( $\text{ا ا ا}$ ) becomes right angle. With the perpendicular  $\alpha F$  ( $\circ \zeta$ ), on the image  $F A' B'$  ( $\text{ا ب ا}$ ) or on the horizontal  $\alpha \gamma$  ( $\circ \epsilon$ ) there occurs a right angle. The image  $A' B'$  ( $\text{ا ب ا}$ ) becomes parallel to the horizontal line  $\alpha \gamma$  ( $\circ \epsilon$ ). In this way it is proven that, the figure  $P' \gamma P$  ( $\text{ط ا ط}$ ) is similar to the figure  $B' B F$  ( $\text{ب ب ا}$ ). The horizontal length  $P J$  ( $\text{ط ا}$ ) in the mirror with 45 degrees of slope from the horizontal, the image  $J' P'$  ( $\text{ا ط}$ ) which is perpendicular to the horizontal line  $\alpha \gamma$  ( $\circ \epsilon$ ) is seen.

Conclusion, when a mirror is placed on the surface, there exist only one image. Namely, in the Figure 4.14, the verticals of the image are seen  $\alpha$  ( $\circ$ ) the end part of the optic axis  $\alpha R C$  ( $\circ \epsilon \zeta$ ). The image  $\gamma$  ( $\epsilon$ ) is considered as a point and from that a perpendicular is drawn to the surface  $P J$  ( $\text{ط ا}$ ). The image is seen only on the mirror of the perpendicular  $\alpha \gamma$  ( $\circ \epsilon$ ), and it is not seen on the other mirrors.

Conclusion; if an observer looks at the mirrors whose surfaces are equivalent to each other, there seen images as many as the mirrors.<sup>253</sup> The images are seen closer to the end part of the optic vertical. It is possible to draw perpendiculars to the surface; therefore many ghost images are seen.

Conclusion; it is possible to determine the surfaces of the mirrors, the position of the image and the reflection points of the mirrors. For example (Figure 4.17);

<sup>253</sup> Hoca İshak Efendi, p. 616.

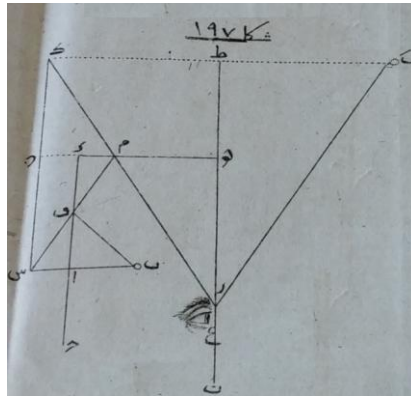


Figure 4.17. Determination of the reflection points of the mirrors

There are the image B (ب), the observer R (ع) and three mirrors  $\gamma F$  (ح ع),  $\alpha \gamma$  (ه ع), C  $\alpha$  (ت) and from the image B (ب) to the mirror  $\gamma \delta$  (ه ٦), the perpendicular A B (ا ب) is drawn. The distance L A (س ا) = B A (ب ا) is satisfied. From the point L (س) on to the ground line  $\gamma \alpha$  (ه ه), the perpendicular K L (ز س) is drawn and V K (ز ك) = K L (ص) is split. B'P (ط ب) = V P (ط ك) is taken. When the lines R B' (ع ب), V L (ك س), L X (م س), T B (ب ف) are reached, T (ف), X (م), J (ر) become reflection points, the image B (ب) is seen at the point B' (ب'). In the triangles A T B (ا ف ب), A T L (ا ف س), the right angles A B (ا ب), T A (ا ف) are relatively equal to the right angles A L (ا س), T A (ا ف). In the point A (ا) the angles are perpendicular, A T B (ا ف ب) = A T L (ا ف س) =  $\gamma$  T X (ه ف م) and  $\gamma$  T X (ه ف م) = A T B (ا ف ب). The ray T B (ب ف) reflects at the point X (م). This proves that the ray X T (م ف) reflects at the point J (ر) and the ray J X (ر م) reflects at the point R (ع). The points T (ف), X (م), J (ر) become reflection points. The image B (ب) is seen at the point B' (ب').

Conclusion; according to the characteristics of the flat mirrors, they don't make the image larger or smaller. The size of the image depends on the inclining of the convergence or divergence of the rays<sup>254</sup>. In the flat mirror for the ray angle to be equal to the reflection angle the needed convergence or divergence cannot occur if the reflection distance stays the same. Accordingly, the size doesn't get bigger or smaller.

Conclusion; according to the characteristics of the flat mirrors, they don't change the size of the image. This is because the shape of the image that the existing scheme of rays does not change in this type of mirrors. In consequence of this absence of change, if the observer is in the reflection point, he sees the size of the image equal to the size of the object.

<sup>254</sup> Hoca İshak Efendi, p. 617.

Conclusion; in the reflecting or indining mirror, the focus becomes the point where the rays and the temperature gathers, and then this type of mirror is called a concave mirror. A flat mirror lacks this type of a focus point; therefore it cannot be a concave mirror. In this case, a flat mirror is different than a concave mirror. A concave mirror can change the shape of the image.

Conclusion; when the flat mirror revolves around its own axis, the arc which is spanned by the image becomes the smaller version of the arc created by the rotation of the mirror.

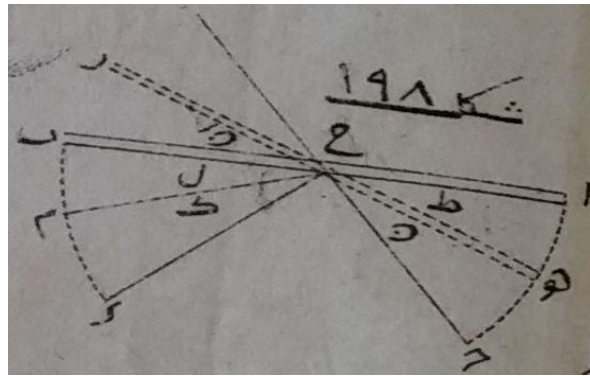


Figure 4.18. Determining the position of an image after the rotation of a flat mirror.

For example (Figure 4.18); firstly, the mirror is placed in the position B A (ب ا). Then assume that the image  $\delta Z$  (د ز) is placed in a position where from  $\gamma$  (ح) to the ray angle A F  $\delta$  (ا ح د) which equals to the reflection angle B F  $\gamma$  (ب ح د). Meaning that; when it is positioned at the point of where the sum of the angles P (ط), K (ك) are equal to the sum of the angles W(و), V(ك), then even if the mirror B A (ب ا) revolves about the point till the position J a (ج ا)<sup>255</sup>, the image of the object F (ح) travels less distance than  $\alpha A$  (ا) which is also less than the distance travelled by the mirror. In the former position B A (ب ا) of the mirror, the angle B F  $\gamma$  (ب ح د) i.e. the areas K (ك) and P (ط) are equal to the angle A F  $\delta$  (ا ح د). In the second position, the ray angle B F J (ب ح ج) becomes equal to the reflection angle  $\alpha F \delta$  (ا ح د). In every rotation of the aforementioned mirror on the arc  $\alpha A$  (ا), the  $\gamma$  (ح) end of the reflected ray depicts the arc B  $\gamma$  (ب ح). This describes the condition B  $\gamma$  (ب ح) = 2.  $\alpha A$  (ا). When B F  $\gamma$  (ب ح د) = A F  $\delta$  (ا ح د) is satisfied, the arc  $\alpha A$  (ا) becomes =  $\frac{1}{2}$  F A (ح ا), then the angles K (ك), P(ط) become opposite to each other. Since the angles K (ك), K' (ك') are the reflection rays in the second position, they are equal to each other. The

<sup>255</sup> Hoca İshak Efendi, p. 618.

angle P (ط) equals to the angle K (ك). Then the arc becomes  $F \alpha (\alpha \text{ ح}) = \alpha A (\alpha \text{ ا})$ , and the arc  $\alpha A (\alpha \text{ ا})$  becomes  $= \frac{1}{2} F A (\alpha \text{ ح}) = \frac{1}{2} \gamma B (\alpha \text{ ب})$ .

Conclusion; when the mirror rotates, the images also rotate. The magnitude of their speed is relative to their distances from the mirror. The depicted arc is smaller than the arc depicted by the mirror. The quantity of the distance from the mirror for the half of the aforementioned arc becomes an arc area. For this reason, when one looks at a vessel full of water to the display of the sun or the moon, the image will be seen to maintain a large distance in case the vessel is destroyed.

Conclusion; when it is intended to observe the displacement direction corresponding to the image seen by two flat mirrors (Figure 4.19);

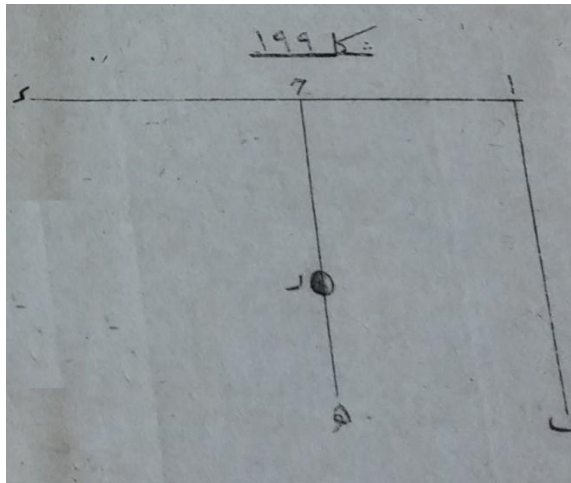


Figure 4.19. Formation of vision on perpendicular mirrors

If the mirrors B A (ب ا), F A (ح ا) are placed perpendicular to each other, the right angle B A  $\gamma$  (ب ا  $\epsilon$ ) occurs. The image Z (ز) residing on the line  $\alpha F (\alpha \text{ ح})$  becomes distant from the mirror  $\gamma A (\epsilon \text{ ا})$  by being perpendicular to the line<sup>256</sup>  $\gamma A (\epsilon \text{ ا})$  on the direction  $\alpha (\alpha)$ . And the image being in equal distance from the mirror B A (ب ا), becomes distant to the mirror  $\gamma A (\epsilon \text{ ا})$ . Its image is transferred in the mirror B A (ب ا) in the direction B (ب).

### Second Part is on Concave and Convex Mirrors

The simple rules seen so far will provide an easy understanding to the upcoming subject. The negative and positive locations of the intersection of curved mirrors and

<sup>256</sup> Hoca İshak Efendi, p. 619.

burning properties will be given in the cone section of the text in detail. Other topics like the change of the size of the image can be applied for concave spherical mirrors. Secondly, (Figure 4.20) the shape  $K \varepsilon R$  (ك ء ع) becomes a concave spherical mirror.

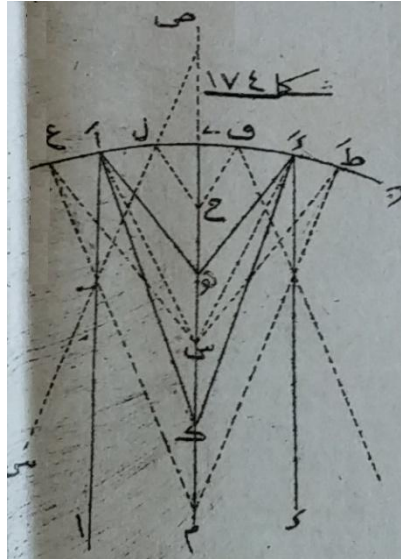


Figure 4.20. Concave spherical mirrors.

It becomes an empty sphere with its center is the point  $V$  (ك) and  $A'V$  (ا ك),  $\gamma'V$  (ء ك) are perpendicular to its surface. These radii send an optic perpendicular. The radius  $\varepsilon V$  (ء ك) which cuts the arc  $K R$  (ك ء) into half is named half of the axis and the other two sides are named as the axis of the mirror. Parallel rays  $A'A$  (ا ا),  $\gamma'\gamma$  (ء ء) that are present in the points  $\gamma'A$  (ء ا) and that their distances from the axis are equal, are gathered at the position where two rays occur and the reflection angle becomes equal to the incident ray angle. In the mirror where the arc  $\gamma'A$  (ء ا) is assumed to be very small, if a cylinder consists of these parallel rays and with a base diameter  $\gamma'A$  (ء ا) is assumed, the small arc being in the light beam might be perceived equal to the angle<sup>257</sup>. If the arc is very small, it might be accepted as a straight line and in this way the parallel rays are gathered at that point. And if (Figure 4.21); the ray  $\varepsilon F$  (ء ح) occurring in the concave spherical mirror  $\varepsilon B J$  (ء ب ج) has the angle of the ray  $V \varepsilon F Z$  (ك ء ح و) parallel to the axis  $B A$  (ب ا) with a slope of 60 degrees, then the reflection line would unite with the axis at the pole  $B$  (ب). Each of the angles  $B \varepsilon V$  (ب ء ك) and  $B V \varepsilon$  (ب ك ء) are from the reflection item and from the parallelism of the lines  $\varepsilon F$  (ء ح),  $B A$  (ب ا) are equal to the angle  $F \varepsilon V$  (ح ء ك) and each of them are 60 degrees, even the angle  $\varepsilon B V$  (ء ب ك) is 60 degrees.

<sup>257</sup> Hoca İshak Efendi, p. 620.



after reflection, all rays do not coalesce. Now if the slope is known, the radius portion which is obtained from the reflected rays can be extracted. For example; if  $\angle V J F$  (ح ر ك) = 3 degrees, and even the angle  $\alpha V J$  (و ك ر) is 3 degrees, then the angle  $\angle V \alpha \gamma$  (ك و ء) becomes 87 degrees. The line  $V \gamma$  (ك ء) is the sine 9,986,295 of the angle  $\angle V \alpha \gamma$  (ك و ء). The angle  $\angle V \alpha$  (ك و) is the sine 1,000,000 of the right angle  $\alpha \gamma V$  (ك ء و). Then it becomes  $\alpha V$  (و ك) -  $\gamma V$  (ء ك) =  $\alpha R$  (و ع) = 13,705 which is the radius portion obtained from the reflected rays. As it is proven, all the rays reflected parallel to the axis reflect between the points  $\alpha$  (و) and  $R$  (ع). The line  $B V$  (ب ك) becomes equal to the line  $\gamma V$  (ء ك) which is also equal to the line  $J V$  (ر ك). Then  $\alpha R$  (و ع) :  $B V$  (ب ك) = 13,705 : 19972090 is satisfied. The part  $\alpha R$  (و ع) becomes 1/1457 of the radius  $B V$  (ب ك). If the slope of the ray angle is equal to 3 degrees, the portion obtained from all the reflections becomes 1/1457 and even the slope of the ray  $\angle V J F$  (ح ر ك) increases the point  $\alpha$  (و) gets closer to the surface of the mirror. Like it is explained before<sup>259</sup>, as the portion  $R \alpha$  (ع و) of the Radius which is obtained from the reflected rays increases, the angle  $\angle V J F$  (ح ر ك) gets bigger and vice versa. Then  $\angle V J F$  (ح ر ك) =  $\angle B V J$  (ر ك ب) is satisfied, since the magnitude of the angle  $\angle B V J$  (ر ك ب) is the perimeter of the mirror  $B J$  (ر ب), as the perimeter of the mirror decreases, the magnitude of the radius  $\alpha R$  (و ع) decreases, the perimeter increases. After the rays, which are parallel to the axis and which occur in the mirror whose perimeter is 6 degrees, are reflected, their sum is taken to be equal to 1/1457 of the radius. The rays unite. With their help, the focus point occurs where the bright spot is seen. And the image appears here. The observer sees the bright spot in the parallel beam of light at the confluence of the cylinder axis at which they are occurred. Secondly, beams of light and fire grow, during combustion, as they gather at one point caustic substances are melted and frozen. A concave spherical (trough) surface obtained in this way is called a concave mirror. It is proven that, the occurrence of radiation in this way, if the degrees of the mirror which reflects the parallel rays were small and for example if it was 8 or 10 degrees, the burning point would be in the middle of the radius, meaning that it would be in the  $\frac{1}{4}$  of the axis of the open sphere. And since sun lights are parallel in appearance, if the axis  $X V \epsilon$  (م ك ء) of the concave spherical mirror  $K \epsilon R$  (ر ء ع) is held towards the sun, the sun would firstly be seen in the point  $\alpha$  (و) which is  $\frac{1}{4}$  of the axis of concave. Secondly, rays occurring in this place create the corresponding impact. For this reason, with preserving their current

<sup>259</sup> Hoca İshak Efendi, p. 622.

situation, the image that is seen far away from the mirror<sup>260</sup> surface is firstly due to the fewness of surface concavity or magnitude of the empty sphere. Thirdly, when the image is seen with the help of the parallel rays, fire appears at a distance far from the mirror. Seeing by the image, occurrence of the fire happens in the focus point which is approximately far  $\frac{1}{4}$  of the axis. This effectiveness of the mirrors were known by the old times philosophers. In ancient history, it is written that ships at a distance of 500 feet are burned by this type of mirrors. On the other hand, to burn ships at such distance, the diameter of mirrors must be 2000 feet which exceeds the manpower to build. Therefore this information is denied or considered as a result of human imagination. However if these ships are not at the distance of 500 feet but close enough, then the described situation might occur, this is the only way it is accepted. As the burning point of the burning mirror is considered as a circle, the axis becomes the point  $\alpha$  ( $\circ$ ), its perimeter  $\gamma \acute{A} \acute{A}$  ( $\acute{\epsilon} \acute{\lambda}$ ) is restricted by the end parts of the rays reflected from the other points and rays are far from the point  $\epsilon$  ( $\angle$ ). As this circle's diameter decreases, other situations, as explained, focus point becomes intensified. Namely, by the sun rays reflected by the concave mirror, burning occurs in the other mirror's diameter of the burning point which is very narrow, and which shows a severe impact. And, if a ray is sent to the point  $\alpha$  ( $\circ$ ), reflection angle becomes the incident ray angle which is occurred by the light beam. The lines  $\gamma \acute{\gamma}$  ( $\acute{\epsilon} \epsilon$ ),  $A \acute{A}$  ( $\acute{\lambda}$ ) become parallel. As it is explained before, the incident ray angle which is occurred<sup>261</sup> by the parallel lines  $\gamma \acute{\gamma}$  ( $\acute{\epsilon} \epsilon$ ),  $A \acute{A}$  ( $\acute{\lambda}$ ) becomes equal to the reflection angle and unites at the point  $\alpha$  ( $\circ$ ). And this type of mirrors can be used in bringing light to a far distance with having sun rays in the focus point and reproducing light rays like explained in cone science, for coequal mirrors. And if the illuminated object is in the center V ( $\acute{\kappa}$ ) of the concave, all the rays coming perpendicular to the concave spherical mirror would be reflected, the image would appear in the axis and at the illuminated point. And for this reason, if the observer's eye is in the center V ( $\acute{\kappa}$ ), all points of the mirror would seem blurry. And if the illuminated object is in the position X ( $\acute{\mu}$ ) which is far from the mirror's axis or the center, the image would occur between the point V ( $\acute{\kappa}$ ) of the axis and the focus point. The observer in the focus point L ( $\acute{\varsigma}$ ) sees as if the image is in the point V ( $\acute{\kappa}$ ) and it is seen blurry in every point of the mirror. Moreover, the focal point of the image in various states shall be determined by the geometry of the various states.

---

<sup>260</sup> Hoca İshak Efendi, p. 623.

<sup>261</sup> Hoca İshak Efendi, p. 624.

Practical example is given in order to determine the position of the image and the focus point, when the image distance is known in a concave mirror. For example, (Figure 4.22);

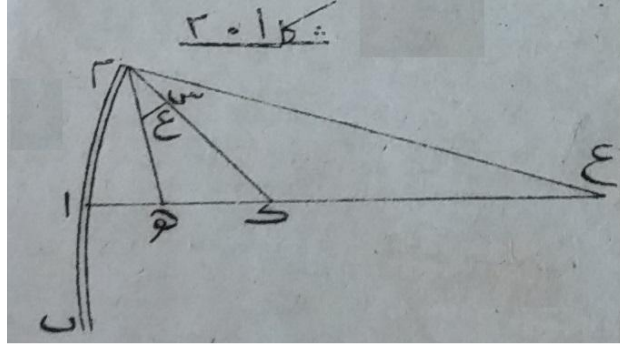


Figure 4.22. Determination of the position of the image and the focus point on a concave mirror

If the concave spherical mirror is  $BA$  (ب ا) and radius of the sphere is  $AV$  (ا ك), the visual vertical line  $XV$  (م ك) and the ray  $XR$  (م ع) which is occurred from the object  $R$  (ع) in the direction of the point  $X$  (م) close to the point  $A$  (ا) will occur. And the ray angle  $L$  (س) will become equal to the reflection angle  $R'$  (ع). As the reflected ray is seen at the point  $\alpha$  (و) in the axis, the image of the object  $R$  (ع) is at the mentioned point. When the line  $A\alpha$  (ا و) is wanted to be obtained at the distance of the focus point, assuming that the arc  $XA$  (م ا) is excessive<sup>262</sup>, the lines  $X\alpha$  (م و) and  $\alpha A$  (و ا) can be taken equal. Then in the triangle  $R X \alpha$  (ع م و), the angle  $R'$  (ع) becomes equal to the angle  $L$  (س) and the line  $VX$  (ك م) divides the angle  $\alpha X R$  (و م ع) into two. And

$$VR (\text{ك ع}) : XR (\text{م ع}) = \alpha V (\text{و ك}) : X\alpha (\text{م و})$$

$$XR (\text{م ع}) = AR (\text{ا ع})$$

$$X\alpha (\text{م و}) = \alpha A (\text{و ا}) \text{ as a result, there will be;}$$

$VR (\text{ك ع}) : AR (\text{ا ع}) = \alpha V (\text{و ك}) : \alpha A (\text{و ا})$ . Now, if it is assumed that  $AR (\text{ا ع})$  the image distance =  $\gamma$  (ع) and the ray  $AV (\text{ا ك}) = F$  (ح) and the focus distance  $A\alpha (\text{ا و}) = \alpha$  (و),

$$VR (\text{ك ع}) = AR (\text{ا ع}) - AV (\text{ا ك}) = \gamma (\text{ع}) - F (\text{ح}) \text{ and}$$

$$V\alpha (\text{ك و}) = AV (\text{ا ك}) - A\alpha (\text{ا و}) = F (\text{ح}) - \alpha (\text{و}) \text{ when these are placed in the equations,}$$

then we have,

$$\gamma (\text{ع}) - F (\text{ح}) : \gamma (\text{ع}) = F (\text{ح}) - \alpha (\text{و}) : \alpha (\text{و})$$

$$\gamma \alpha (\text{ع و}) - F \alpha (\text{ح و}) = F \gamma (\text{ح ع}) - \alpha \gamma (\text{و ع}) \text{ and}$$

$$\gamma \alpha (\text{ع و}) + \gamma \alpha (\text{ع و}) - \alpha F (\text{و ح}) = F \gamma (\text{ح ع}) \text{ namely,}$$

<sup>262</sup> Hoca İshak Efendi, p. 625.

2.  $\gamma \alpha (\epsilon \circ) - \alpha F (\circ \tau) = F \gamma (\tau \epsilon)$  then the law  $\alpha (\circ) = F \gamma (\tau \epsilon) / (F (\tau) - 2. \gamma (\epsilon))$  is obtained and it becomes the law of concave spherical mirrors. Now if the image exists in the point  $\alpha (\circ)$ , the ray in the point  $X (\rho)$  will reflect at the point  $R (\xi)$  and the focus will be at the point  $R (\xi)$ . Hence;

$A \alpha (\circ) = \gamma (\epsilon)$  and  $R A (\xi \rho) = R X (\xi \rho) = \alpha (\circ)$  will occur.

$V A (\xi \rho) = F (\tau)$  and also  $\alpha V (\circ \xi) = F (\tau) - \gamma (\epsilon)$

$R V (\xi \rho) = \alpha (\circ) - F (\tau)$  then

$X \alpha (\rho \circ) : R X (\xi \rho) = V \alpha (\circ \xi) : R V (\xi \rho)$  it means that;

$\gamma (\epsilon) : \alpha (\circ) = \alpha (\circ) - \gamma (\epsilon) : \alpha (\circ) - F (\tau)$  in this similarity

$\alpha \gamma (\circ \epsilon) - F \gamma (\tau \epsilon) = F \alpha (\tau \circ) - \gamma \alpha (\epsilon \circ)$  will occur.

2.  $\gamma \alpha (\epsilon \circ) - F \alpha (\tau \circ) = F \gamma (\tau \epsilon)$  then,

$\alpha (\circ) = F \gamma (\tau \epsilon) / (F (\tau) - 2. \gamma (\epsilon))$  is obtained.

Now, firstly, if  $\gamma (\epsilon) = \frac{1}{\infty}$  is assumed,

$F \gamma (\tau \epsilon) / (F (\tau) - 2. \gamma (\epsilon)) = \frac{1}{\infty} : \frac{2}{\infty} - F (\tau) = \frac{1}{\infty} : \frac{(\infty F (\tau) - 2)}{\infty} = \frac{F (\tau)}{\infty F (\tau) - 2} = -\frac{1}{\infty}$  focus

will be negative and the image size will become excessive, also it will be at the back side of the mirror. Secondly, if the quantity  $\gamma (\epsilon)$  is less than the quantity  $F. \frac{1}{2} (\tau)$ , it means that, if the quantity  $2. \gamma (\epsilon)$  is less than the quantity  $F (\tau)$ , the mentioned rules will be;  $2. \gamma (\epsilon) - F (\tau) : F (\tau) = \gamma (\epsilon) : \alpha (\circ)$ <sup>263</sup> and the quantity  $2. \gamma (\epsilon) - F (\tau)$  will be negative and even the quantity  $\alpha (\circ)$  will be negative so the image will be at the back side of the mirror. Thirdly, if  $\gamma (\epsilon) = F (\tau) \frac{1}{2}$  i.e. if  $F (\tau) = 2. \gamma (\epsilon)$ , then  $0 : F (\tau) = \gamma (\epsilon) : \alpha (\circ)$  and the ratio of zero to  $F (\tau)$  will be equal to infinity. Then even the ratio  $\gamma (\epsilon) : \alpha (\circ)$  will be equal to infinity. Focus will be very far and the image will be in front or at the back side of the mirror. Fourthly, if the quantity  $\gamma (\epsilon)$  is bigger than the quantity  $\frac{1}{2}. F (\tau)$  i.e.  $2. \gamma (\epsilon), F (\tau); 2. \gamma (\epsilon) - F (\tau) : F (\tau) = \gamma (\epsilon) : \alpha (\circ)$  will be obtained. The quantity  $2. \gamma (\epsilon) - F (\tau)$  will be positive and the image will be in front of mirror. Fifthly, if  $\gamma (\epsilon) = \frac{3}{4}. F (\tau)$ , then the rule  $F \gamma (\tau \epsilon) / (F (\tau) - 2. \gamma (\epsilon))$  will become  $\frac{3.F.F (\tau \tau)}{4} : \frac{6.F (\tau) - 4.F (\tau)}{4} = \frac{3.F.F (\tau \tau)}{2.F (\tau)}$  i.e.,  $\frac{3}{2}. F (\tau) = \alpha (\circ)$ . Sixthly, if  $\gamma (\epsilon) = F (\tau)$ , then  $F \gamma (\tau \epsilon) / (2. \gamma (\epsilon) - F (\tau)) = F F (\tau \tau) / (F (\tau) - 2.F (\tau)) = F F / F = F (\tau) = \alpha (\circ)$ . Seventhly, if  $\gamma (\epsilon) = 2.F (\tau)$ , then  $F \gamma (\tau \epsilon) / (2. \gamma (\epsilon) - F (\tau)) = 2. F F (\tau \tau) / (4.F (\tau) - F (\tau)) = F (\tau). 2/3 = \alpha (\circ)$ . Eighthly, if  $\gamma (\epsilon) = 3.F (\tau)$ , then  $3.F F (\tau \tau) / (6.F (\tau) - 1. F (\tau))$

<sup>263</sup> Hoca İshak Efendi, p. 626.

=  $F(\text{ح}) \cdot 3 / 5 = \alpha(\text{و})$ . Ninthly, if  $\gamma(\text{ء}) = \infty$ , then the law  $F \gamma(\text{ح ء}) / (F(\text{ح}) - 2 \cdot \gamma(\text{ء}))$  will become =  $F \infty(\text{ح}) / (F(\text{ح}) - 2 \cdot \infty)$  i.e.  $F \infty(\text{ح}) / 2 \cdot F(\text{ح})$ . And  $\alpha(\text{و}) = F(\text{ح}) \frac{1}{2}$  is proven this way.

Conclusion, from all of these rules it is understood that, as the object gets far away from the mirror, the image gets far away on the other side of the mirror. And if the object is placed in the midpoint of the half of the axis, the image will occur at the infinity. As the object gets closer to the axis, the image gets closer to the mirror and if the object is placed in the axis, the image will be composite. And if the object gets closer to the side X (م) from the center, the image gets closer to the mirror from the center. If the object is taken to a far distance, the image comes to the point  $\alpha(\text{و})$  i.e. in the midpoint of half of the axis. If the object is placed as in the first or second situation (Figure 4.20), the observer L (س) will be seen beyond the mirror<sup>264</sup> and the visible light will be seen in the point N (ص) where the right optic cone N L (س ص) unites with the normal N F (ح ص). Additionally the point N (ص) is the point where the rays that are reflected from the object comes and again reflects at the mirror. And in this way focus is obtained. When the illuminated object is between the midpoint of the ray  $\alpha(\text{و})$  and the mirror K R (ج ع), the mentioned mirror is no longer a concave mirror. In these situations, the object looks larger than it is. Like (Figure 4.23);

---

<sup>264</sup> Hoca İshak Efendi, p. 627.

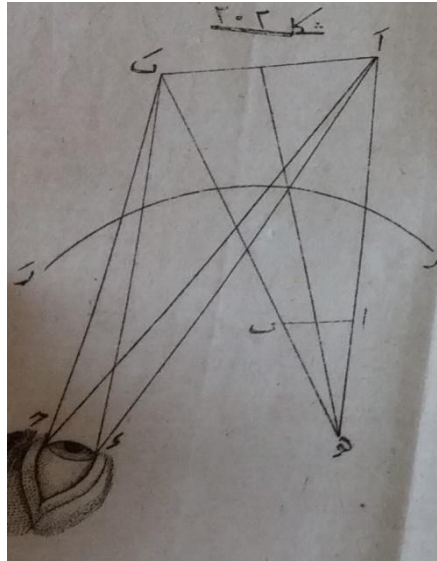


Figure 4.23. Formation of vision on a concave spherical mirror.

The object  $BA$  ( $\text{ب ا}$ ) is seen in the position  $\gamma \delta$  ( $\text{ع ٦}$ ). The  $A$  ( $\text{ا}$ ) end of the image is in the point  $A'(\acute{\text{ا}})$  where the normal  $A'A \alpha$  ( $\acute{\text{ا}} \text{ا} \text{ا}$ ) of the mirror  $J'J$  ( $\text{ج ج}$ ) and the optic cone  $\gamma F A'$  ( $\text{ع ح ا}$ ) unite. The other  $B$  ( $\text{ب}$ ) end is in the point  $B'(\acute{\text{ب}})$  where the normal  $B'B \alpha$  ( $\text{ب ب ا}$ ) to the mentioned mirror and the optic cone  $\gamma F B'$  ( $\text{ع ح ب}$ ) unite. Since the image  $B'A'$  ( $\text{ب ا}$ ) is the right side of the big triangle  $\alpha B'A'$  ( $\text{ا ب ا}$ ), its similar and smaller triangle  $\alpha BA$  ( $\text{ا ب ا}$ )'s right side becomes bigger than the image  $BA$  ( $\text{ب ا}$ ).

Secondly, the image  $BA$  ( $\text{ب ا}$ ) and the ghost image  $B'A'$  ( $\text{ب ا}$ ) are similarly on a right side, the points  $A'A$  ( $\acute{\text{ا}} \text{ا}$ ) occur on the other right side and are positioned symmetrically with the points  $B'B$  ( $\text{ب ب}$ ). If the rays  $\gamma A'$  ( $\text{ع ا}$ ) and  $F B'$  ( $\text{ح ب}$ ) coming from the  $B'(\acute{\text{ب}})$ ,  $A'(\acute{\text{ا}})$  ends of the object, unites once before arriving to the eye lens, the object does not turn upside down as proven. However, the ray which combines before being perceived in the lens, if the rays coming from the right  $A$  ( $\text{ا}$ ) point led to the left and if the rays coming from the left  $B$  ( $\text{ب}$ ) point led to the right, the rays coming from  $A'(\acute{\text{ا}})$  point will touch the eye in the  $F B'$  ( $\text{ح ب}$ ) direction. As a result, the eye will see the point  $A'(\acute{\text{ا}})$  at  $B$  ( $\text{ب}$ ) and the point  $B$  ( $\text{ب}$ ) at  $A'(\acute{\text{ا}})$ . In this way rays occur twice and therefore the observer sees the object<sup>265</sup> upside down. If the rays going through the points  $B'A'$  ( $\text{ب ا}$ ) occur three times, points appear on their original positions. Hence if the occurred rays are odd then the object is seen straight and double. In the last example, with the merger of the rays  $\gamma A'$  ( $\text{ع ا}$ ),  $F B'$  ( $\text{ح ب}$ ) to the pupil, the image  $B'A'$  ( $\text{ب ا}$ ) of the object  $BA$  ( $\text{ب ا}$ ), the object  $BA$  ( $\text{ب ا}$ ) is seen in its original

<sup>265</sup> Hoca İshak Efendi, p. 628.

situation. In other situations, i.e., if the distance between the center of the object and half of the axis is bigger than the center, the final version of the occurred rays appear twice as shown in the Figures 4.20 and 4.23, and the image will be upside down. Since it is expected to have difference in between the hollow cylindrical mirror and spherical mirror, firstly, cylinder mirror portion to be assumed to be formed (Figure 4.24);

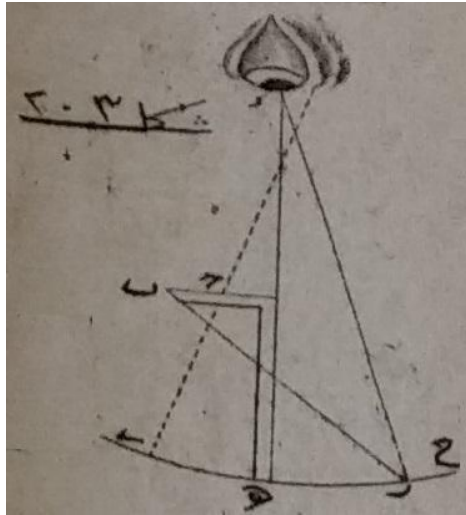


Figure 4.24. Cylindrical mirrors.

equal and parallel like the arc  $\varepsilon F$  ( $\varepsilon \text{ ح}$ ) many circles and some assumed parts of spherical mirrors gather at one point on the axis. Secondly, attempting to put a vertical to hollow cylinder mirror's basis would yield a straight line. In this way, with one face of the circle being an arc shows the influence of spherical mirrors. Namely, since the observed cylinder positioned in between the first quarter on the arc's axis  $\alpha V$  ( $\alpha \text{ ك}$ ) and its own arc, it is seen large and in its original situation and in the middle of the mirror. And the mentioned mirror length being a straight line, image's size doesn't increase with length and vanishes in its horizontal side. Secondly, if the object is positioned in between the center  $V$  and one of the first quarters of the object, then it is seen upside down and blurry. And in all of the situations<sup>266</sup> convex mirrors are unable to unite the rays and their focus is not real so they are not burning mirrors. However, the virtual focus becomes a point which is beyond the mirror, at the end of the right optic cone where the observer sees the bright spots. For example (Figure 4.25); the observer  $\gamma \alpha$  ( $\gamma \alpha$ ) sees the object  $B A$  ( $\text{ب ا}$ ) in the convex spherical mirrors  $P J$  ( $\text{ط ج}$ ). The point  $A'(\acute{ا})$  is accepted to be a focus point on beyond the

<sup>266</sup> Hoca İshak Efendi, p. 629.

mirror P J (ط ج). Rays which are extracted from the point A' (أ') and are established to the optic cone A' γ α (أ' ε α), unite in the mentioned point.

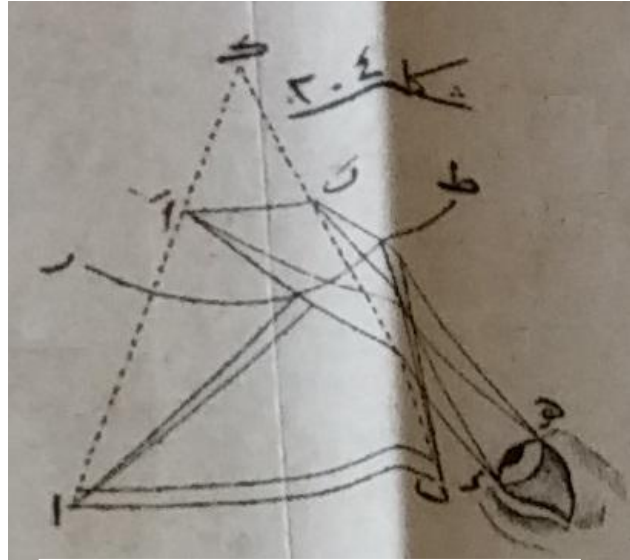


Figure 4.25. Convex spherical mirrors.

The mentioned cone extends in between mentioned rays from the point A' (أ') of the observer to the normal V A' A (أ' أ ك) which is drawn to the convex surface P J (ط ج). The point B' (ب') is the focus of the optic cone B' γ α (ب' ε α). The aforementioned cone extends till it reaches the normal V B B (ب ب ك) which is created from the object's point B' (ب') to the convex surface P J (ط ج).

Practical example is given in order to determine the focus point and the position of

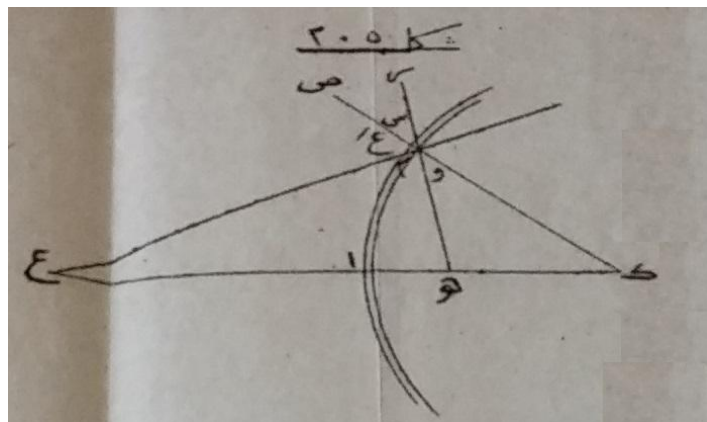


Figure 4.26. Determination of the focus point and the position of the image in a convex spherical mirror.

the image when half of the axis and the distance of the object are known in the convex spherical mirror. For example (Figure 4.26); if the convex mirror X A (م ا), half of the axis A V (ا ك), the object R (ع), its distance R A (ع ا) and the axis V A R (ك ا ع) is given and if the focus is asked, the ray X R (م ع) would be in the point X (م) which is close to the point A (ا). When unbounded normal X V (م ك) and the current ray X R (م ع) are drawn to the current point, the ray angle N X R (ص م ع) or R' (ع) becomes equal to the reflection angle J X N (ص م ر) or L (س). X J (م ر) light which diverges further and is present in the axis of the convex mirror will be reflected and<sup>267</sup> intersect with the axis at the point α (و). With the point α (و) being negative, the image occurs beyond the mirror.

Now in the triangle R X V (ع م ك);

There will be the equality;

$$R V (ع ك) : X R (م ع) = R X V (ع م ك) \text{ sine} : X V R (م ك ع) \text{ sine}$$

The angle R X V (ع م ك) along being obtuse angle, its completed sine becomes equal to the sine;

$$R (ع) = L (س) = Z (و) = \alpha X V (و م ك) \text{ sine. Therefore;}$$

$$R V (ع ك) : X R (م ع) = \alpha X V (و م ك) \text{ sine} : X V R (م ك ع) \text{ sine}$$

And in the triangle α X V (و م ك)

$\alpha V (و ك) : X \alpha (م و) = \alpha X V (و م ك) \text{ sine} : X V \alpha (م ك و) \text{ sine}$  or depending on X V R (م ع ك) it becomes  $R V (ع ك) : X R (م ع) = \alpha V (و ك) : X \alpha (م و)$  and depending on the arc X A (م ا) it becomes  $X \alpha (م و) = \alpha A (و ا)$

$R V (ع ك) : X R (م ع) = \alpha V (و ك) : \alpha A (و ا)$  is obtained. Now,

If,  $R A (ع ا) = X R (م ع) = \gamma (\epsilon)$  and  $V A (ك ا) = F (\zeta)$  and  $A \alpha (ا و) = \alpha (\omega)$  is assumed,

In the relation  $F V (\zeta ك) = \gamma (\epsilon) + F (\zeta)$  and  $F V (\zeta ك) = F (\zeta) - \alpha (\omega)$ , if the following equations are placed,

$$\gamma (\epsilon) + F(\zeta) : \gamma (\epsilon) = F (\zeta) - \alpha (\omega) : \alpha (\omega)$$

$$\gamma \alpha (\epsilon \omega) + F \alpha (\zeta \omega) = F \gamma (\zeta \epsilon) - \alpha \gamma (\omega \epsilon)$$

$$\gamma \alpha (\epsilon \omega) + \gamma \alpha (\epsilon \omega) + F \alpha (\zeta \omega) = F \gamma (\zeta \epsilon), \text{ i.e.,}$$

$$2. \gamma \alpha (\epsilon \omega) + \alpha F (\omega \zeta) = F \gamma (\zeta \epsilon) \text{ and } \alpha (\omega) = \frac{F \gamma (\zeta \epsilon)}{F(\zeta) + 2\gamma(\epsilon)} \text{ are obtained.}$$

In this case, firstly, if  $\gamma (\epsilon) = \frac{F(\zeta)}{\infty}$ , then;

<sup>267</sup> Hoca İshak Efendi, p. 630.

$$\frac{F\gamma(\epsilon)}{F(\tau)+2\gamma(\epsilon)} = \frac{FF(\tau)}{\infty} : \frac{2\cdot F(\tau)}{\infty} + F(\tau) = \frac{FF(\tau)}{\infty} : \frac{F(\tau)\infty+2\cdot F(\tau)}{\infty} = \frac{F(\tau)}{\infty} \text{ will be obtained.}$$

Then the focus  $\alpha(\phi) = \frac{F(\tau)}{\infty}$  will be positive and its distance from the mirror will be greater.

Secondly, if the quantity  $\gamma(\epsilon)$  is much less than  $F(\tau) \frac{1}{2}$ , i.e., if the quantity  $2\cdot\gamma(\epsilon)$  is less than  $F(\tau)$ , the explained rule will be;

$$2\cdot\gamma(\epsilon) + F(\tau) : F(\tau) = \gamma(\epsilon) : \alpha(\phi) \text{ expanded to this equation.}$$

Thirdly, if  $\gamma(\epsilon) = F(\tau) \frac{1}{2}$ , i.e.,  $F(\tau) = 2\cdot\gamma(\epsilon)$  then,

$$F(\tau) + F(\tau) : F(\tau) = F(\tau) \frac{1}{2} : \alpha(\phi) \text{ or}$$

$$2 : 1 = \frac{1}{2} : \alpha(\phi) \text{ will be obtained and } \alpha(\phi) = F(\tau) \frac{1}{4}.$$

Fourthly, if the quantity  $\gamma(\epsilon)$  is bigger than the quantity<sup>268</sup>  $F(\tau) \frac{1}{2}$ , i.e., if the quantity  $2\cdot\gamma(\epsilon)$  is bigger than  $F(\tau)$ , then;

$$2\cdot\gamma(\epsilon) + F(\tau) : F(\tau) = \gamma(\epsilon) : \alpha(\phi) \text{ will be obtained.}$$

Fifthly, if  $F(\tau) = \gamma(\epsilon)$ , then;

$$\frac{FF(\tau)}{F(\tau)+2\cdot F(\tau)} = \frac{FF}{3\cdot F} = \frac{F(\tau)}{3} = \alpha(\phi) \text{ will be obtained.}$$

Sixthly, if  $\gamma(\epsilon) = 2\cdot F(\tau)$ , then;

$$4\cdot F(\tau) + F(\tau) : F(\tau) = 2\cdot F(\tau) : \alpha(\phi), \text{ i.e., } 5\cdot F(\tau) : F(\tau) = 2\cdot F(\tau) : \alpha(\phi) \text{ and } \alpha(\phi) = \frac{2\cdot FF(\tau)}{F(\tau)} = F(\tau) \frac{2}{5} \text{ will be obtained.}$$

Seventhly, if  $\gamma(\epsilon) = \infty$ , then;

$$\frac{F(\tau)\infty}{F(\tau)+2\cdot\infty} = \frac{F(\tau)\infty}{2\cdot\infty} = F(\tau) \frac{1}{2} = \alpha(\phi) \text{ will be obtained. As a result, the claim is proven.}$$

Conclusion, the distance taken by the image, which is stimulated by the movement of the object, is determined by the mentioned ways. Namely, if the object is placed close to the mirror, its image beyond the mirror will be seen close to it and if the object becomes distant, the image will also become distant. When the object goes far with a distance of half of the radius, the image goes far with a distance of more than one-fourth of the radius. When the object goes far more with a distance of more than radius, the image goes far more than one-fourth of the radius. However, when the object goes far with the amount of the total radius, the image is seen at a distance of one-third of the radius. When the object is placed beyond the radius, the image goes far on the other side of the mirror. When the

<sup>268</sup> Hoca İshak Efendi, p. 631.

object goes far from convex surfaces to infinity, the image stays at a distance of half of the radius.

Conclusion, the rules for convex and concave spherical mirrors may also be applied to flat mirrors. Namely, the position where light is present is very small. Considering the rules  $\alpha(\phi) = \frac{F\gamma(\zeta\epsilon)}{F(\zeta) - 2\gamma(\epsilon)}$  ve  $\alpha(\phi) = \frac{F\gamma(\zeta\epsilon)}{F(\zeta) + 2\gamma(\epsilon)}$  of flat, convex and concave spherical mirrors, when a radius =  $\infty$ ,  $F(\zeta) = \infty$  is assumed, become  $\alpha(\phi) = \frac{\infty\gamma(\epsilon)}{\infty - 2\gamma(\epsilon)}$  or  $\frac{\infty\gamma(\epsilon)}{\infty + 2\gamma(\epsilon)}$ , i.e.  $\alpha(\phi) = \frac{\infty\gamma(\epsilon)}{-\infty}$  or  $\alpha(\phi) = \frac{\infty\gamma(\epsilon)}{\infty}$ , i.e.  $\alpha(\phi) = -\gamma(\epsilon)$  or  $\alpha(\phi) = \gamma(\epsilon)$  for flat mirrors. If the flat mirror is assumed to be a part of the concave spherical mirror, the distance of the image beyond the mirror will be equal to the distance of the object. The image will be shown with minus sign according to the rules of concave spherical mirrors. And if it was a convex spherical mirror  $\alpha(\phi) = \gamma(\epsilon)$  would be satisfied, i.e. image's distance would be equal to object's distance and curvature sign would be taken positive, all the equations based on geometry this way would be accepted as correct. And from this statement it becomes clear that, firstly (Figure 4.25) the eye B A (ب ١) sees the image of the object at the behind the mirror. Secondly, the image is seen between the center V (ك) of the convex mirror and the mirror surface P J (ط ر). For the optic cones to exist the normals V A' A (ك ١), V B' B (ك ب ١) are needed. These approach curvedly and unite at the center. Thirdly, this type of mirrors shrinks the image size. The line A' B' (١ ب) becomes the right side of the small triangle among the similar triangles A' V B' (١ ك ب), A V B (١ ك ب) and the line A B (١ ب) becomes the right side of the big triangle. Fourthly, the image is in the position of the object. Namely, the point A (١) is in the position A' (١) and the point B (ب) is in the position B' (ب). Fifthly, as B A (ب ١) approaches to the mirror, the image B' A' (ب ١) is seen the largest if its distance to the point V (ك) is assumed equal in all situations. As the object B A (ب ١) gets closer to the mirror P J (ط ر), the angle B V A (ب ك ١) increases and also the right side B' A' (ب ١) increases. Other than this<sup>269</sup>, as the object A (١) gets closer to the convex spherical mirror J P (ط ر), the eye (١ ب) sees the image A' (١) closer to the aforementioned surface. It is clear that, as the point A (١) gets closer to the point of contact with the surface, the eye  $\alpha\gamma(\phi\epsilon)$  sees the image A' (١) on the mirror surface. Thus firstly, as the object B A (ب ١) gets closer to the mirror, its image becomes larger along with resulting at the normal V B (ك ب), V A (ك ١). Secondly, contrarily, as the object B A (ب ١)

<sup>269</sup> Hoca İshak Efendi, p. 632.

becomes distant to the mirror, the image gets closer to the surface JP (ط ج) to the axis V (ك) and becomes smaller.

Conclusion, it is possible to form a mirror in order to make an object to be seen the same, in variety, closer or farther. For example; (Figure 4.27); assume that; on the surface W X (ل م); the convex spherical mirrors W V P (ل ك ط), δ B A (ب ا), the concave spherical mirrors α γ δ (و ء ٦), P F J (ط ح ر); and the flat mirrors X A (م ا), J α (ر و) are

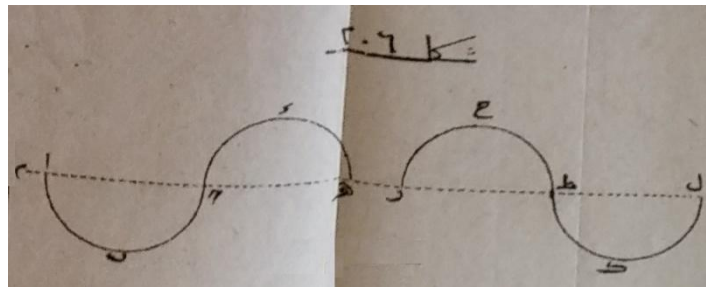


Figure 4.27. Flat, concave and convex spherical mirrors on the same surface.

aligned. When the object is left in the position T (ف) which is considered to be exterior, images and their distances are observed equal to their objects in the flat mirrors, smaller in the convex spherical mirrors, larger and in variety in the concave spherical mirrors.

Convex cylindrical mirrors change the image shape as concave spherical mirrors, but in an opposite way. Namely, the image of the object does not increase in length or decrease in the flat mirrors. However, concave spherical mirrors increase the image width. In fact, they increase the angle with the collection from right to left of the length of the emitted beam. And the convex spherical mirrors, contrarily, by emitting the rays to the right end left sides of the length and so by separating the rays and reducing their tendency to approach, they decrease the angle. In this way, object shapes can usually be changed by cylinder mirrors, but it is odd<sup>270</sup> that, the images appear blurry. When this blurred image is observed through a concave cylinder mirror, a smooth figure appears again. And also, another figure being blurry because of its excessive length is seen in its smoothest shape in convex spherical mirrors. It is a common property of cone and pyramid mirrors to show smooth images as blurry and blurry images as smooth. This amount of information is considered adequate for this section.

<sup>270</sup> Hoca İshak Efendi, p. 633.

### The third section is about the tools for rotating and reflecting images

In tools like microscope, glasses and binoculars pertaining to reflective optics, the magnitude of the tendency of these tools' convex spherical mirrors is according to the curvature of the mirror. Namely, as the distance which is able to magnify all the rays coming from the end parts of a glass object and which is able to magnify the apparent magnitude of the angle of the object remain constant, the growth is according to the mirror curvature. And by microscope, even the smallest things which are not visible to the eye can easily be seen. As follows (Figure 4.28);

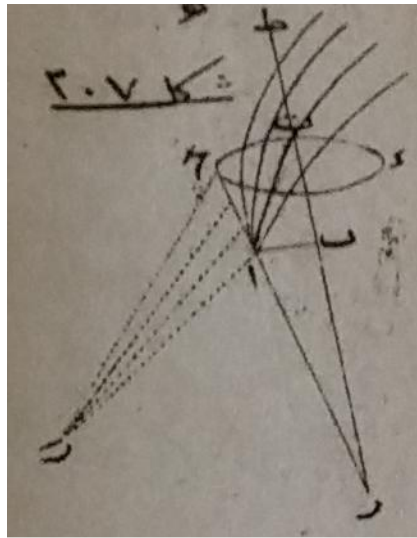


Figure 4.28. Formation of vision in a microscope.

If the small object  $BA$  ( $\text{ب ا}$ ) is assumed to be in the focus  $B$  ( $\text{ب}$ ) of the glass  $\gamma \delta$  ( $\text{ع د}$ ) and the eye  $C$  ( $\text{ع}$ ) is assumed to be in the point  $P$  ( $\text{ط}$ ), the edge  $A$  ( $\text{ا}$ ) will be seen scattered and blurred. However, when the eye is in a closer position<sup>271</sup>, the divergence tendency of the rays forming the optic cone would be too much in order the image to be seen. Hence they cannot unite on the other side of the eye lens, in the other position and because of the glass  $\gamma \delta$  ( $\text{ع د}$ ) the aforementioned glasses would become parallel and close to each other. For these reasons, firstly the total of the inclined rays can be collected in the eye as if it passes through the large distance, i.e. as if the eye sees the point  $A$  ( $\text{ا}$ ) clearly. In this text, sighting distance that one is able to is given nine unit values. Secondly, the eye sees the point  $J$  ( $\text{ج}$ ) as it is at a distance of 9 unit values from  $J$  ( $\text{ج}$ ). Thirdly, the eye sees the point  $A$  ( $\text{ا}$ ) at  $J$  ( $\text{ج}$ ) end of the optic cone  $JA \delta$  ( $\text{ج ا د}$ ), at  $JA$  ( $\text{ج ا}$ ) =  $JB$  ( $\text{ج ب}$ ) = 9 unit values away from its real distance. Fourthly, since the object  $BA$  ( $\text{ب ا}$ ) which can be brought to the

<sup>271</sup> Hoca İshak Efendi, p. 634.

point A (ا), is present at the point B (ب) along with the other small objects, the eye can clearly identify the small object B A (ب ا) without using a microscope. Similarly, another object which is close to the eye and equal to the point B A (ب ا), is identified equal to the object B A (ب ا) at a distance of nine unit values at the point J (ج) where the image size is larger than the object. Hence, it is proved that the glass shows the object larger than it actually is. Fifthly, optic cones which are extracted from the ends B (ب), A (ا) of the object by the glass, have the tendency to approach to each other. It's because that when the outward angle increases during the ray coming to the eye lens as described, the glass shows the small object B A (ب ا) bigger. The amount of enlargement of the objects done by a simple microscope can be found in this way<sup>272</sup>. The eye in the position C (ت) sees the objects with an angle of B C A (ب ت ا) at the point J (ج), i.e. at nine unit values distance with an angle of B J A (ب ر ا).

$$B C A (ب ت ا) : B J A (ب ر ا) = J B (ج ب) : C B (ت ب)$$

And it is understood that, as the glass becomes distant from the eye, the image size gets smaller. Using a crystal bowl with full of water instead of glass, will result in upcoming situations. Firstly, the aforementioned object will be seen larger at focus. Secondly, small parts of the object enlarge and can be seen individually. Thirdly, when a lighted candle is placed in the dark night, many rays unite at the focus of the bowl and when a very small object is placed at the focus, it can be seen by a careful eye. Fourthly, due to the tendency of the focus point, when an object with an ability of flammability as pink kava is placed at the focal, fire will occur as the sunlight passes through the object. Therefore, objects which are proper to be use instead of microscope have to perform the aforementioned functions fully or partially. A compounded microscope consists of two, three or four glasses. The glass on the side of the object is called the objective lens and the one on the side of the eye is called ocular lens. As follows, Figure (4.29);

---

<sup>272</sup> Hoca İshak Efendi, p. 635.

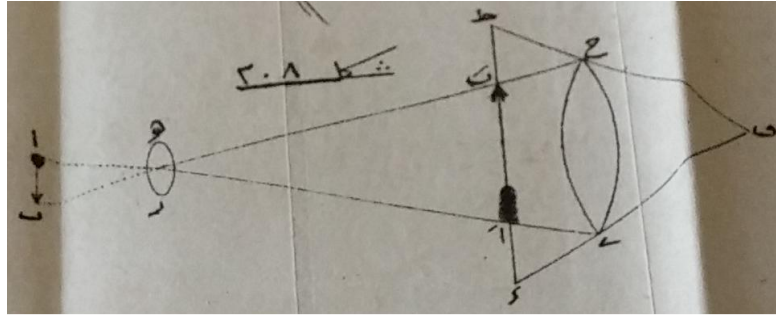


Figure 4.29. A compounded microscope with two glasses.

When the small object  $B A$  ( $\text{ب ا}$ ) is placed in front of the objective lens  $J \alpha$  ( $\text{ج ا}$ ), it illustrates the images of every point of the ray cones occurring from  $B$  ( $\text{ب}$ ),  $A$  ( $\text{ا}$ ) and other image points. As explained, it supposed to enlarge the whole image of  $B' A'$  ( $\text{ب ا}$ ) in the front glass. Now if the image  $B' A'$  ( $\text{ب ا}$ ) is seen from the objective lens  $\varepsilon F$  ( $\text{ا ح}$ ) with a simple microscope and the image occurs actually<sup>273</sup>, it enlarges with a magnitude of  $B' A'$  ( $\text{ب ا}$ ), and become as large as  $\gamma P$  ( $\text{ا ط}$ ). In this way, it is understood that the small object  $A B$  ( $\text{ا ب}$ ) can be seen larger than it is by two glasses. Small objects are seen more clearly and closer to the eye by a small portion of a glass sphere or all portions of a small sphere. This simple tool is named as microscope. The image is seen clearly by aforementioned glasses placed on top of each other or the inclined position of bounded spheres. For example, a book's letters are seen eight to ten unit values away from then they are seen without using a glass. Eyeglasses are made of these glasses. If the mirrors of these eyeglasses have convex mirrors in the middle and thin mirrors at the end sides, they are used for seeing the close objects. Those who can easily see the far objects but have the challenge to see closer objects, use these glasses. Yet, the one who is able to see further distances but who is unable to see closer i.e. who is hypermetropic will have a lesser curvature so arriving rays will be lesser. Because of the fact that focusing of the lights will be lesser an old person won't see a further distance as clear as a younger person. Young people usually see the letters in the book at a distance of nine unit values and they have to be at a distance more than the curvature of the necessary amount of rays to reach the eye in order to identify the rays which form the optic cone. Now, those who are older and whose eyes curvature is less, rays cannot unite at the retina, unless they look from further<sup>274</sup>, they cannot see the close. In this way, ray diverging tendency becomes less, so they pass through a further point and

<sup>273</sup> Hoca İshak Efendi, p. 636.

<sup>274</sup> Hoca İshak Efendi, p. 637.

they can unite at the eye lens. For this reason, when an old person wants to read, he has to move the book away from more than nine unit values. However, the rays approaching in a bright form lose their brightness proportionate to the square of the distance they passed. For example, long distance rays passing from fifteen unit values are poor for activation of the eye. As fibers in the eye that rays are passing through solidify, movements of the eyes are harder for an old person than it is for a younger person. For this reason, old people use glasses with convex mirrors to overcome the weakness of their eyes. If the bright point which cannot be seen from the distance of fifteen unit values is placed to a distance of seven or eight unit values, rays reach four times denser than the previous situation. Glasses with convex mirrors decrease the curvature of the diverging rays and the image is clarified by the unification of the rays in the eye lens. Those who see the close but cannot see objects further than eight unit values face a situation opposite to this one. Since the curvature of the eye is excessive, refraction of the rays will be denser and they will unite prematurely. Those who can see from a distance of nine unit values can read only if the object is closer to their eyes. This is because when the object is closer, the intensity of the rays approaching to the eye increases. This situation is not because the eye is weak, but because the eye stimulates retina so that the image is not seen scattered<sup>275</sup> and blurred. If myopic people use glasses with concave spherical mirror, i.e. middle part of the glass is thicker than the side parts of the glass, and then rays coming from a distance of nine unit values can unite at the eye lens. Aforementioned glass is a part of the big sphere. Surveillance Binoculars are invented based on this rule. Surveillance Binoculars (Figure 4.30);

---

<sup>275</sup> Hoca İshak Efendi, p. 638.



optic cone being in the focus C (ع). Secondly, the image J X (ج خ) is seen upside down and double, however, since celestial objects are spherical being seen upside down doesn't prevent their observation.

Observation issue; the ratio of the angle at which observer looks with binoculars to the angle of the object's image is equal to the ratio of the sum of the distances of objective and ocular lenses' focus, to the distance of ocular lens focus. For example, Figure 4.31;

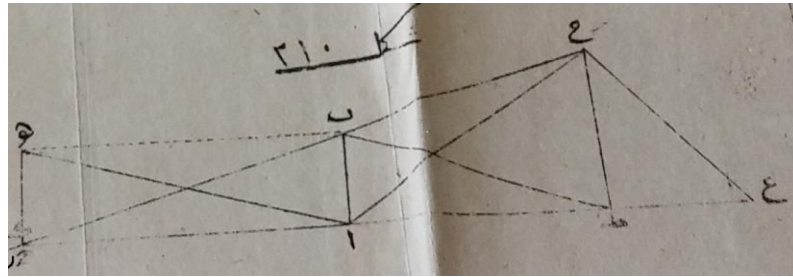


Figure 4.31. Equivalent ratios in Binoculars.

The visible angle J F V (ج ح ك) of the image J V (ج ك) is equal to the mutual angle A F B (ا ح ب). A portion F α (ح و) of the ocular lens and its distance <sup>277</sup> F A (ح ا) from the focus when the normal B A (ب ا) is drawn from the point A (ا) to the portion F α (ح و), the line A α (ا و) is obtained. Then the angle F A α (ح ا و) becomes equal to the angle A F B (ا ح ب) and even that is equal to the image angle. Parallel rays are reflected from the focus R (ع). P F (ط ح) portion of the ocular lens forms the rays. The angle which is enlarged by the focus and binoculars of the ocular lens P F (ط ح), becomes the angle P R F (ط ع ح). And now, when the lines A B (ا ب), P F (ط ح) are perpendicular to the line P F (ط ح), the triangles P δ F (ط ح), A δ B (ا ب) become similar;

$$P F (\text{ط ح}) : B A (\text{ب ا}) = \delta P (\text{ط ب}) : \delta A (\text{ا ب})$$

$$F \alpha (\text{ح و}) = B A (\text{ب ا}) \text{ then,}$$

$$P F (\text{ط ح}) : \delta \alpha (\text{ا و}) = \delta P (\text{ط ب}) : \delta A (\text{ا ب})$$

$$(\delta P (\text{ط ب}) \times \delta \alpha (\text{ا و})) / \delta A (\text{ا ب}) = P F (\text{ط ح}) \text{ is obtained.}$$

And cavity in the aforementioned glass is assumed to be very few and assuming the lines  $\delta \alpha (\text{ا و})$ , P F (ط ح) that are taken as arcs, they might be the magnitudes of the angles

<sup>277</sup> Hoca İshak Efendi, p. 640.

$P R F (\text{ط ع ح})$ ,  $\delta A \alpha (\text{٦ ١ ٥})$  with radiuses  $P R (\text{ط ع})$ ,  $\delta A (\text{٦ ١})$ . Angles are directly proportional to their arcs and with an adequate proportion to their radiuses;

$P R F (\text{ط ع ح}) : \delta A \alpha (\text{٦ ١ ٥}) = P F (\text{ط ح}) / P R (\text{ط ع}) : \delta \alpha (\text{٦ ٥}) / \delta A (\text{٦ ١})$  is obtained, it is taken equal to one of the amounts of  $P F (\text{ط ح})$

$P R F (\text{ط ع ح}) : \delta A \alpha (\text{٦ ١ ٥}) = (\delta P (\text{٦ ط}) \times \delta \alpha (\text{٦ ٥})) / (P R (\text{ط ع}) \times \delta A (\text{٦ ١})) : \delta \alpha (\text{٦ ٥}) / \delta A (\text{٦ ١})$  is obtained, i.e.

$P R F (\text{ط ع ح}) : \delta A \alpha (\text{٦ ١ ٥}) : P F (\text{ط ح}) / P R (\text{ط ع}) : A (\text{١})$  then

$P R F (\text{ط ع ح}) : \delta A \alpha (\text{٦ ١ ٥}) = F P (\text{ح ط}) : P R (\text{ط ع})$  is obtained.

The rate between the angle of the binoculars to the angle of the vision is equal to the rate between the sum of focus distances of objective lens and ocular lens to the focus distance of ocular lens. Hence, the claim is proven.

Conclusion, when the magnitude  $R P (\text{ع ط})$  is less than the magnitude  $R P (\text{ع ط})$ , the increment becomes more.  $A P (\text{١ ط})$  becomes the burning position. As the line<sup>278</sup>  $B P (\text{ب ط})$  converges, the angle  $A P B (\text{١ ط ب})$  can be taken instead of the angle  $P R F (\text{ط ع ح})$  and the magnitude  $A B (\text{١ ب})$  can be taken instead of the magnitude  $P F (\text{ط ح})$ . The ratio of the acute angle to the outward angle will be  $= \frac{B A (\text{ب ١})}{P A (\text{ط ١})} : \frac{B A (\text{ب ١})}{\delta A (\text{٦ ١})} = \frac{A (\text{١})}{P A (\text{ط ١})} : \frac{A (\text{١})}{\delta A (\text{٦ ١})} = F A (\text{ح ١}) : P A (\text{ط ١})$ . With the division of the burning point of outer glass to burning point of landscape glass, mentioned increment is obtained. Namely, if the binoculars is  $A (\text{١})$  and the burning point of its objective lens is  $\alpha (\text{٥})$  and ocular lens is  $\alpha (\text{٥})$  and also if another binoculars was  $B (\text{ب})$  and its objective lens is  $T (\text{ف})$  and ocular lens is  $T' (\text{ف})$ , as a result the rate between the increase in binoculars  $A (\text{١})$  and binoculars  $B (\text{ب})$  will be  $\frac{\alpha (\text{٥})}{\alpha' (\text{٥})} : \frac{T (\text{ف})}{T' (\text{ف})}$ . Now, if  $\alpha (\text{٥}) = 20$  steps, and  $\alpha' (\text{٥}) = 4$  units and  $T (\text{ف}) = 40$  steps and  $T' (\text{ف}) = 6$  units; then it becomes  $A (\text{١}) : B (\text{ب}) = 240/4 : 480/6$  i.e.  $A (\text{١}) : B (\text{ب}) = 6 : 8$  is obtained.

Conclusion, it is understood from the mentioned rules that, as the angle increases, the effect of the image decreases. Rays are prone to diverge. The blurriness doesn't decrease. When there is an increment on one side, the side objective lens will remain the same and the amount of light on the ocular lens will be lesser than the remaining dark area. The magnitude of the dark area is related to the blurriness of the light and the place that the vision occupies. The blurriness will be proportional with the square of the radii of these

<sup>278</sup> Hoca İshak Efendi, p. 641.

areas; also the dark areas will be in proportion to square of the radii of the visions. The diameters of the object's images are proportional to their angles and since the ones arriving to outer glass become equal to burning locations of image glasses. Hence, the area of the mentioned dark places<sup>279</sup> become adequate to be sufficient for the square root of the image glass's burning position. For example, when the binoculars A (ل) the objective lens A (ل) and the image glass  $\alpha'$  (ع) and the binoculars B (ب) the objective lens T (ت) and the image glass T' (ت') are assumed, if  $\alpha$  (ا) = 36 and  $\alpha'$  (ع) = 6 and  $\text{ت} = 4$ , then the ratio of the increment in the binoculars A (ل) to the increment in the binoculars B (ب) will be = 6 : 9 and the ratio of the darkness in the binoculars A (ل) to the darkness in the binoculars B (ب) will be = 16 : 36, i.e.,

$$A (ل) : B (ب) = T' (ت') : \alpha' (ع)$$

Observation binoculars are described like this. Since celestial bodies are spherical, they are observed by two glasses. However, when the position of the ground bodies and the images of their shapes wanted to be known, the situation won't be like this, as four pieces consisting two glasses on each side will be used. As their axis being straight lines, rays coming from the object will unite twice times at the binoculars. And rays unite once from the binoculars to the eye lens. Numbers of unification will be equal and the images will be seen in their positions. And these binoculars are called as close-up binoculars.

When some of the latter scientists revealed some properties of colored rays, it is concluded that, with bigger binoculars i.e. with increased curvature, object's image will be uncompleted. Yet, rays coming from one point of the object extend enough. For this reason, if a concave spherical mirror is placed in the objective lens, with any color of rays the reflection angle occurring in this type of mirror will be equal to the outward angle. All the rays will unite<sup>280</sup> at the burning point of the mirror. Hence, the aforementioned binocular is invented. As follows (Figure 4.32);

---

<sup>279</sup> Hoca İshak Efendi, p. 642.

<sup>280</sup> Hoca İshak Efendi, p. 643.

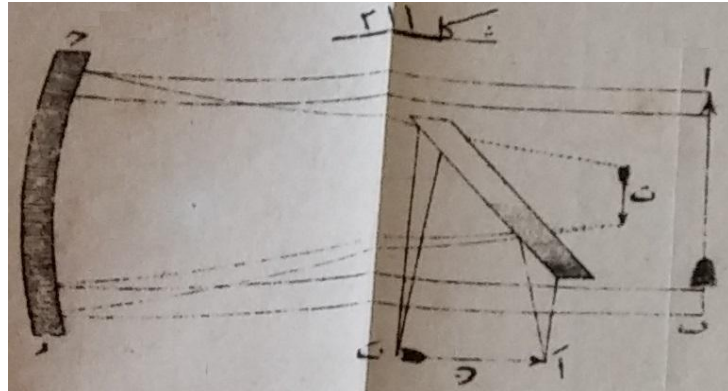


Figure 4.32. Binoculars with a concave spherical mirror placed in the objective lens.

Its diameter is in the middle of the large cylinder, the placed axis of the concave spherical mirror  $\gamma F$  ( $\epsilon \text{ ح}$ ) is in the direction of cylinder axis in the object direction and mirror's burning point  $C$  ( $\text{ت}$ ) is between the mirror and cylinder's open end. Rays reflecting to the concave spherical mirror and coming from the object in the cylinder axis  $B A$  ( $\text{ب ا}$ ), pictures the image of the object at the burning point  $C$  ( $\text{ت}$ ) of the mirror. It is understood from the invention of the binocular that, if the image glass is not placed at the ends of the cylinder and if not placed in the point  $K$  ( $\text{ك}$ ), the image cannot occur. In order rays that come from the image as coming from the object to be reflected at the burning point of the concave spherical mirror, there will be a flat mirror located with 45 degrees from the axis of concave. The image  $B A$  ( $\text{ب ا}$ ) will be at the outer side of the cylinder. It is shown as parallel in the position  $C$  ( $\text{ت}$ ) perpendicular to the axis of the concave spherical mirror. A crystal stone is placed at the point  $K$  ( $\text{ك}$ ) in order to get the increase of the light and burning image for every point of it to be seen. A small cylinder is applied perpendicular to a big cylinder. On it small mirror's image will be reflected in the point  $K$  ( $\text{ك}$ ). Binoculars glass is attached to this small cylinder and in order objects to be seen in their original places, three glasses are put in the binoculars. Now, according to the various sizes of the images or burning points of the concave spherical mirrors, a transfer on to the axis will be required. After the next reflection of the image from the small mirror, in order the image to occur on the mirror's burning point  $K$  ( $\text{ك}$ ), the small mirror will be driven away up and down on the axis.<sup>281</sup>

<sup>281</sup> Hoca İshak Efendi, p. 644.



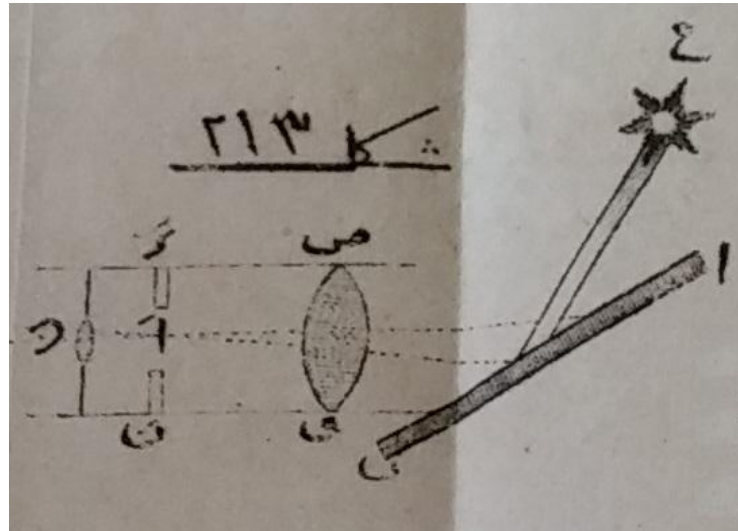


Figure 4.34. Formation of vision in a solar microscope.

The mirror B A (ب ا) is placed facing the Sun F (ح). Rays reflecting from the mirror and being in the crystal stone N T (ص ف) become parallel to the axis. An animal is placed in the middle A' (ا') of the line  $\gamma \gamma' B'$  (ب ب'). In order light to penetrate<sup>282</sup> till it reaches the glass K (ك) of the light microscope, a hole is bored in. And with this,  $\alpha \gamma \gamma' B'$  (ب ب' ا ا') which is a dark area, sunlight come through here from inside this hole. With the help of little glass rays reach to the fabric  $\alpha \gamma$  (ا ا') and if the aforementioned animal i.e. an ant, a flea or any visible on their species is transparent, their instruments and organs and other limbs will be pictured clearly on the mentioned surface. And as long as it is transparent, its outer surface i.e. its feet and head and other outer parts will be seen in a larger scale. For the mentioned animal to be seen like this, rays forming the optic cone pass through various points. They become solid by the glass T N (ص ف), and they again become transparent by the binoculars glass K (ك). Lights of the little glass K (ك) occurs from the cones formed by lights coming from various parts of the animal and them being prone to converge. When the distance between these rays is larger and their tendency to diverge increases their distance on the fabric becomes larger and as a result parts and various organs of the mentioned animal will be pictured larger and more clearly. And the animal itself is seen bigger than it actually is.

Secondly, assume a rectangular prism shaped like a chest, a hole is bored in one of the parallel vertical sides of it and a cylinder is placed in it. A glass is placed parallel to the length of the chest and to the horizontal axis. On the open cylinder above the chest a flat

<sup>282</sup> Hoca İshak Efendi, p. 645.



front on the axis<sup>284</sup> C R (ت ع) on the point R´ (ع) a lighting candle and a cylinder K R (ز ع) is placed. The axes of the mentioned glasses reach through the direction K R (ز ع) and light might pass the point C (ت) or might be reflected from the point R (ع) so between the points R´ K´ (ع ز) the glass γ´ A´ (ء´ أ) and the cylinder R K (ع ز) exists. Some of the light reflected from the candle R´ (ع) will be present in the glass γ´ A´ (ء´ أ). Being present in another candle’s opposite vertical side, light will transmit to the concave mirror L C ε (س ع ت) and be reflected to the glass γ´ A´ (ء´ أ). And light being denser and curved by the glass this way illustrates the coloured and transparent vision to the point K´ (ز). Light cones arising from different points multiply by the joining of two glasses of the cylinder K R (ز ع) and illustrate the image on the white surface Z N (ص و). And with this tendency light cones arising from different parts of the image K´ (ز) approach curvedly and join this way. With their tendency to diverge, they will be present at the surface Z N (ص و) and so the small image present in the point K´ (ز) will be seem larger via light. And this tool being similar to a headlight, it’s named as magic lantern. With this information the third article is completed.<sup>285</sup>

#### 4.4. The Entrance of Modern Concepts of Optics “Photoelectricity”, “Diffraction” and “Interference” to Ottoman Turkey

##### 4.4.1. Optical Studies after Mecmua-i Ulum-i Riyaziye in Ottoman State

This section of the study aims to find an answer to the question of when the modern optical terms like photoelectric, diffraction and interference has entered to Ottoman Turkey and to examine the optical literature<sup>286</sup> which developed since 1833 when *Mecmua-i Ulum-i Riyaziye* was published. *Mecmua-i Ulum-i Riyaziye*, a 4 volume encyclopaedia of positive sciences was written by Chief Minister İshak Efendi to stimulate Ottoman State’s cultural life, introduce new sciences to Ottoman State and to improve Turkish to a level that can express these sciences. This treatise enabled the education of young scholars who wanted

<sup>284</sup> Hoca İshak Efendi, p. 647.

<sup>285</sup> Hoca İshak Efendi, p. 649.

<sup>286</sup> For the examination of Optics’ Literature in 1833-1940 *Osmanlı Tabii ve Tatbiki Bilimler Literatürü Tarihi* (edited by Ekmelleddin İhsanoğlu) is used as the main resource.

to specialize on the modern sciences of the age by upgrading the transference of the modern concepts which initiated by İbrahim Müteferrika.<sup>287</sup> After the printing of *Mecmua-i Ulum-i Riyaziye* the sources that related with optics in Ottoman Turkey continued to enrich between 1833-1937 by both translations and exegesis that devoted to the older texts. After 1890, with Salih Zeki's publications on mathematics and physics, it can be said that a new era in which advanced physics gained importance has begun in Turkey.<sup>288</sup> Among Salih Zeki's engrossed studies in physics *Hikmet-i Tabiiyye* which was published in 1896 in Istanbul, is especially important. This is mainly because of its eliciting explanations on general and experimental physics' terms and because it had been the basic source for physics education in Turkey for many years. The conclusion of this study that aimed to observe the course of optical knowledge in Ottoman Turkey is formed by Refik Fenmen's 1937 published work, *Madde ve Ziya*. This work both includes modern optical terms like photoelectric, diffraction, interference; and conduces to the entrance of quantum mechanics' subjects to Turkey.

The first work on optics in literature after *Mecmua-i Ulum-i Riyaziye* is Karim B. İbrahim's (present in 1268/1852) *Ziya'al-Başa'ir fi İlm al-Manazır*, which he wrote utilizing from a book in his own library; İbn al-Haytham's treatise *Kitab al-Manazır*. Later, Muhammed Bayyumi (d. 1268/1852) translated French physicist Eugene Pecllet's work *Traite Elemantaire de Physique* and published as *Kitab al-Tabi'yya* in 1828. *Risala fi'l-Zav*, a work that is related with light and introduced to the literature by Muhammed Bayyumi is also a translation from Eugene Pecllet. Hayrullah B. Abdulkhak Molla (d. 1283/1866), who was the nephew of Mustafa Behçet Efendi, the son of Abdullah Molla and the father of the poet Abdulkhak Hamid, wrote a work related with physics, named *Mesail-i Hikmet*. The tenth article of *Mesail-i Hikmet*, which he wrote while he was a minister in Mekteb-i Tibbiye, is about concave mirrors in optics. Later, one of the greatest mathematicians of the last ages of Ottoman and at the same time the teacher of Vidinli Tevfik Paşa, Küçük Tahir Paşa (d. 1284/1867) wrote a work that includes general subjects of physics, named *Hikmet-i Tabiiye*. Addition to this work, Necip Efendi's (present in 1288/1871) *Malumat-ı Muhtasara Risalesi* and Süheyl Bey's (ölm. 1289/1872) *Kütüb-i Muhtelif-i Hikmet-i*

<sup>287</sup> Hüseyin Gazi Topdemir, "Türk Fizik-Optik Tarihi Üzerine", *Türkiye Araştırmaları Literatür Dergisi*, Volume 2, Issue 4, İstanbul 2004, pp. 135-151.

<sup>288</sup> Aykut Kazancıgil, "XIX. ve XX. yüzyıllarda Türkiye'de fizik ve tıbbi fizik tarihi ile ilgili yayınların notlu kaynakçası", *Osmanlı Bilimi Araştırmaları*, Volume 6, Issue 2, İstanbul 2004, pp. 320-323.

*Tabiiyeden Ebhas-i Mütenevviayı Havi Tercüme Mecmuası* can be given as examples to the books that involve general subjects of physics.<sup>289</sup> One of the teachers of Mekteb-i Tıbbiye, Hafız Mehmed (d. 1292/1875) prepared a book called *Hikmet-i Tabiiye* to be studied in the 5<sup>th</sup> and 6<sup>th</sup> grades of Darüşşafaka. The book consists of six chapters including optical subjects as reflection, refraction and propagation of light. Besides, Muhammed Favzi B. al-Tabib al-Mısri's (present in 1879) *al-Zavahir al-Badi'a fi 'İlm al-Tabi'a* and Mustafa Hami Paşa's (d. 1878) *Zubdat al-Ulum* are works that involves general subjects of physics. Ali Necib Paşa-Zade Ahmed Hamdi's work (present in 1888) *İlaveli Mecmua-ı Müfide* that was compiled and translated from French sources includes physics' subjects in addition to chemistry, mathematics and industry. Ahmed Tevfik's (d. 1890) *Hikmet-i Tabiiye* which he translated from Herbert N. Gasson to use as a course book in Darülfünun's 6<sup>th</sup> grade includes optics-related subjects as the propagation of light, refraction and telescopes.<sup>290</sup>

Antranik Gırcikyan (d. 1894), who is also known as Antranik Pasha, was an Armenian origin Ottoman doctor, as well as a physicist. He gave physics lectures at Mekteb-i Tıbbiye-i Mülkiye and translated Adolphe Ganot(1804-1887)'s *Traite Elemeentaire de Physique* as *İlm-i Hikmet-i Tabiiye*<sup>291</sup>. The second volume of this work includes subjects like; theories on light, formation of shadow, the speed of light, photometry, photometry laws, mirrors, formation of the solar spectrum, optical gadgets, multiple refraction. Farther, Mehmed Said Bey wrote *Hikmet-i Tabiiye Tatbikatı* which involves general subjects of physics and shows the applications of the laws of physics. Abdüllatif Efendi wrote *Hikmet-i Tabiiye* that mentions about the reflection of light, the preservation of light and mirrors in the third volume of it. Both Yenişehirli-zade Halid Eyüb's (d. 1901) *İslam ve Fünun* and Mahmud Favzi al-Hakim al-Mısri's (d. 1901'den sonra) *Al-Zavahir al-Badi'a fi 'ilm al-tabia* are related with general subjects of physic. Esad Feyzi (d. 1902) also has a work that is qualified to be indicated as an introduction to physics course book.<sup>292</sup>

<sup>289</sup> Ekmeleddin İhsanoğlu (ed.), *Osmanlı Tabii ve Tatbiki Bilimler Literatürü Tarihi*, IRCICA press, İstanbul 2006, Vol. 1, pp. 165-184.

<sup>290</sup> İhsanoğlu, pp. 189-237.

<sup>291</sup> A. Ganot, *İlm-i Hikmet-i Tabiiye*, Antranik Kırçikyan (Trans.), Mekteb-i Tıbbiye-i Şahane Press, İstanbul 1876.

<sup>292</sup> İhsanoğlu, pp. 268-340.

Among Ali Rıza's (present in 1905) works that were prepared to be taught in girls schools<sup>293</sup>, *Kızlara Mahsus Malumat-ı Nafîa Dürus-u Eşya*, 3. *Sene* includes subjects related with light and *Kızlara Mahsus Malumat-ı Nafîa Dürus-u Eşya*, 4. *Sene* includes general subjects of physics. Furthermore, Hamid Efendi (present in 1905) discussed the observation of the Moon using a telescope in his article *Teleskop* and İbrahim Mustafa Bey (d. 1910) described basic physical knowledge using 100 shapes in his book *Mabadi'al-Tabi'iyya*. Also, İsmail Hakkı's *Hikmet-i Tabiiye* is about physical subjects and M. M. Omar's (present in 1913) *Muhtasar fi'l-Zav* is about the physics of light. Zeyni-Zade Mehmed Hazık's (present in 1916) *Malumat-ı Fenniye* is a scientific textbook that mentions about subjects related with light.<sup>294</sup>

Mahmud Celaleddin's (d. 1917) article, named *Hurdebin yahud Mikroskop* introduces the device, microscope. This work, which also gives general information about lenses, describes the areas of usage of microscope and its benefits for various branches of science. Hakkı (present in 1917) wrote an article called *Mikroskop yani Hurdebin*, in which he mentions the invention, usage and history of microscope and introduces some parts of the device. Ali Yusuf's (present in 1918) work, *Bahs fi Falsafat al-Zav: İbn al-Haysam ve Muallafatuhu ve Arau'hu fi Bahs al-Zav* examines İbn al-Haytham's life, works and his treatise on optics, *Kitab al-Manazır*.<sup>295</sup>

#### 4.4.2. Salih Zeki's Treatise *Hikmet-i Tabiiye* and the Succeeding Optical Works

Salih Zeki (d.1921), who spread a great effort on the acknowledgement and improvement of modern mathematical and physical sciences' education in Turkey, is also the first historian of science in the country. After the 1915 regulation of Darülfünun which Salih Zeki served in it as the rector, innovations in physical education were initiated and

<sup>293</sup> Until the Tanzimat Reform Era in Ottoman State, girls' education couldn't be systematized and was restricted with Ottoman elementary-primary schools that give education from age 5-6 for 3-4 years. With the declaration of the Tanzimat Reforms in 1839, this situation began to change. The first girls schools in Ottoman State were established after the declaration of intention of Padishah Abdülmecit (1839-1861) in 1845, which also obligated primary schools in Ottoman State and mentioned about a university called Darülfünun to be established in İstanbul. For detailed information see Yahya Akyüz, "Osmanlı Son Döneminde Kızların Eğitimi ve Öğretmen Faika Ünlüer'in Yetiştirilmesi ve Meslek Hayatı", <[http://dhgm.meb.gov.tr/yayimlar/dergiler/Milli\\_Egitim\\_Dergisi/143/1.htm](http://dhgm.meb.gov.tr/yayimlar/dergiler/Milli_Egitim_Dergisi/143/1.htm)> (29.06.2015)

<sup>294</sup> İhsanoğlu, pp. 361-563.

<sup>295</sup> İhsanoğlu, pp. 565-595.

the education of advanced physics actualized under the leadership of Salih Zeki.<sup>296</sup> Salih Zeki wrote down many treatises using his given lectures in Darülfünun. Salih Zeki's two books; *Hikmet-i Tabiiye Dersleri* and *Muhtasar Hikmet-i Tabiiye* involve a section, named discussion on light. On the other hand, the book he prepared according to 9<sup>th</sup> grade of Sultani Schools of Ottoman State named *Küçük Hikmet-i Tabiiye* includes the subjects of propagation of light and the preservation of light. Besides these, his book *Mukaddimat-ı Ulum-i Tabiiyeden Yeni Hikmet ve Kimya* that he prepared for students of İdadi, Sultani, Darümuallimin, and Darülfünun, includes the subjects of light, reflection of light and refraction of light.<sup>297</sup>

Salih Zeki's book *Hikmet-i Tabiiye* was published 4 times from 1896 and was used as a basic reference book for physics for many years in Turkey. It includes a chapter named *Mebhas-ı Ziya* related with optics. *Mebhas-ı Ziya* consists of 5 sections and 92 subtitles. The first section in the introduction part is related with light and light incidents and the following sections are related with transparent, semi-transparent and solid objects, light gadgets, geometric and theoretical statements on light. After the introduction part, the first chapter is related with the propagation of light and includes subtitles as lights propagation in an area, light beams, solar and lunar eclipse, lightened pictures, speed of light and light intensity. Herein two laws on light intensity are given, claiming 1) light intensity would be inversely proportional to the square of the distance from the light source 2) light intensity would be proportional to the sine of the angle occurring between the light beams and the surface.<sup>298</sup>

The second part of *Mebhas-ı Ziya* is about the reflection of light and begins with the definition of reflection. There are two laws given about the reflection of light; 1) the incoming ray and the reflected ray has to be on the same surface and 2) the incoming ray has to be equal to the reflected ray. Apart of these; subjects like the propagation of light, the formation of vision in flat mirrors, equal mirrors, kaleidoskop, formation of vision in concave and convex mirrors, focal point, the location of focal point, secondary focal and central points and the effect of the distance between the object and the mirror to the formation of the vision are present.<sup>299</sup> The third part is about the refraction of light. It

---

<sup>296</sup> Aykut Kazancıgil, *Osmanlılarda Bilim ve Teknoloji*, Gazeteciler ve Yazarlar Vakfı Press, İstanbul 1999, p. 316.

<sup>297</sup> İhsanoğlu, pp. 638-644.

<sup>298</sup> Salih Zeki, "Mebhas-ı Ziya", *Hikmet-i Tabiiye*, Kerabet Matbaası, İstanbul 1921, pp. 1-29.

<sup>299</sup> Zeki, pp. 30-76.

includes two laws about refraction; 1) the incoming ray and the refracted ray has to be vertical to the surface of refraction and 2) the ratio between the sine of the incident ray and the refracted ray should be constant. In the text, the proofs of these laws are given and also the phenomenon of total reflection and the formation of mirage are defined. These subjects are followed by, the transmission of light through a triangular prism, concave and convex lenses, the determination of the focal point in concave and convex lenses, the formation of vision in concave and convex lenses.<sup>300</sup>

The fourth section of the book is on the analysis of the nature of light and mainly Newton's observation of the separation of sunlight into seven colors is discussed. Yet Newton, explored that sunlight consists of seven different colored light rays and he developed his own theory on color. In this section; the formation of the spectrum by passing white light through the prism, the colors composing this spectrum and their degrees of refraction and the regeneration of white light are discussed. Also, the proof of Newton's observation on white light rays consisting of seven colors is given. Under the title of the fabric of the sun spectrum, spectrum's composition of three sections is signified. These sections are; light beams, heat beams and chemical beams. A device named spectroscope, providing information on the chemical nature of light transmitted from celestial bodies is introduced. The discovery of W. Hyde Wollaston about the spectrum having dark lines on it, which occurred while he was doing an observation on sunlight spectrum in 1802, is also mentioned. Furthermore, the exploration of Joseph Fraunhofer in 1814 of the dark lines' existence as a result of the sunlight's transmittance through colder gases and the exploration of G. Robert Kirchoff and Robert Wilhelm Bunsen in 1856 of the correlation between the spectrum lines and the temperature is discussed. As a result, it's mentioned that detailed information can be achieved on the chemical nature of Sun and stars by this method and some examples of the conclusions on spectrum examinations are given.<sup>301</sup>

The fifth section is titled as "Alat-ı Ziyaiyye" and introduces some optical gadgets. In this section, there exists information about the usage of microscope and telescope, in addition to the introduction of Galileo's telescope, Herschel's telescope, Yuri Gagarin's

---

<sup>300</sup> Zeki, pp. 76-109.

<sup>301</sup> Zeki, pp. 109-141.

telescope and Newton's telescope. Information on the dark room is also given in this part.<sup>302</sup>

After Salih Zeki's *Hikmet-i Tabiiye*, İsmail Hasanayn Paşa's (d. 1924) work *Kitab al'Tabia*, related with sound and light exists in literature. Besides, İsmail Sa'di (present in 1924) wrote a book, *Hikmet-i Tabiiye Mesaili* which includes subjects of sound and light. Ahmed Şükri's (d. 1926) book, *Fenn-i Mihanik*, which involves mostly mechanical subjects, mentions about geometry and optical studies in its first chapter.<sup>303</sup> Also Ahmed Refik Yaltkaya's (d. 1931) work *Fenn-i Makine*'s second part is about light. Apart from these, Mehmed Şevki (d. 1931) wrote a book basically about medical physics, called *Hikmet-i Tabiiye-i Tıbbiye Dersleri*; he also includes some optical subjects as mirrors, refraction of light, vision disorders, eye glasses and Franklin eyeglass. Mehmed Şevki also has another book *Yeni hikmet-i Tabiiye* that involves general optical subjects.<sup>304</sup>

Kuru-zade Osman Cevdet Karaosman (d. 1931) prepared a treatise called *Fizik* for the 11<sup>th</sup> grade students of Sultaniye Schools. This treatise includes subjects like; the statement of light, the analogy of light, refraction of light and refraction laws, flat mirrors, concave and convex mirrors, reflection of light and reflection laws, eye, vision, propagation of light. He has another treatise called *Fizik* which he prepared for Darümuallim primary schools. This treatise includes optical subjects like; the statement of light, the propagation of light, light intensity, refraction and reflection of light, mirrors, physical examinations on light, the analysis of light. He also prepared a *Fizik* named course book for 9<sup>th</sup> grade Makteb-i Sultaniye and 5<sup>th</sup> grade Sultani School of Girls, including subjects like light, refraction of light, reflection of light, examinations on eye, the analysis of light.<sup>305</sup>

Selanikli Fazlı Necib's (d. 1932) treatise *Mebahis-i Muhtasara-i Fenniye* contains subjects on optics like; light, luminous tool and matters, mirage formation and its causes, sound and light, heat and light, colors, the source of colors, the preservation of eyes and issues on eye-glasses. However, Necib Asım Yazıksız (d. 1935) wrote down a book named *Ziya ve Hararet* in order to give general information on light and heat and Fuad Münir

---

<sup>302</sup> Zeki, pp. 141-173.

<sup>303</sup> İhsanoğlu, pp. 674-698.

<sup>304</sup> İhsanoğlu, pp. 738-741.

<sup>305</sup> İhsanoğlu, pp. 742-744.

Bener (present in 1949) wrote down *Eşya Dersleri, 6 Devre-i Aliye İkinci Sene* including light and refraction of light from optics.<sup>306</sup>

Mehmed Tevfik (1933'te sağ)<sup>307</sup> who was one of the professors of general physics in İstanbul Darülfünun University, has a treatise named *Fizik-i Umumi Dersleri* on general subjects of physics. This treatise contains optical subjects like; light, the propagation of light, reflection of light, reflection laws, flat mirrors, refraction of light, laws of refraction, accumulation of light, accumulators, the participation of spherical burning mirrors, the separation of light, the ability of basic lights to accumulate, light gadgets, information on reaction of light, general features of optical gadgets and microscope. Mehmed Tevfik has another treatise with the same name *Fizik-i Umumi Dersleri* being prepared in order to be lectured as a course book in the Faculty of Science. This one includes subjects on light as the source of light, the transmission, separation and reflection of light. He also wrote down an article named *Temevvücat-ı Elektrikiyye* introducing electromagnetic waves.<sup>308</sup>

Fahir Yeniçay, who used to be a student in Darülfünun University Faculty of Science, states that Mehmed Tevfik gave lectures on “Geometrical Optics” and “Physical Optics” writing down the formulas of the lectures using old letters. Yeniçay also stated that Mehmed Tevfik was leading the laboratory of geometrical optics.<sup>309</sup> In the Journal of Darülfünun Faculty of Science (after 1929 it was named the Journal of İstanbul Darülfünun Faculty of Science) 24 articles of Mehmed Tevfik were published in 1924-1933, that some of these were translations. Among these articles, one named “İnikas ve İnkisar kanunlarının Hususi bir prensip ile istihracı” has special importance for it compared Newton's theory on the particle nature of light and Huygens's theory on the wave nature of light and proposed a new method to find the laws of reflection and refraction of light. According to Feza Günergun, among the articles of Mehmed Tevfik that were published in the Journal of İstanbul Darülfünun Faculty of Science, only this one has the quality of a true research paper.<sup>310</sup> On the other hand, in the Journal of İstanbul Darülfünun Faculty of Science, there exists an article of Mehmed Tevfik on optics named “Tayf-ı Şemsinin

<sup>306</sup> İhsanoğlu, pp. 753-899.

<sup>307</sup> Abdülkadir Özcan, “Mehmed Tevfik Bey”, **TDVİA**, İstanbul 2003, Vol. 28, pp. 536-537.

<sup>308</sup> İhsanoğlu, pp. 759-760.

<sup>309</sup> Osman Bahadır, *Cumhuriyetin İlk Bilim Dergileri ve Modernleşme*, İzdüşüm press, İstanbul 2001, p. 77.

<sup>310</sup> Erdal İnönü and Osman Bahadır, *Türkiye'de Temel Bilimlerde İlk Araştırmacılar*, Büke Press, İstanbul 2007, p. 132.

imtidadı” discussing the formation of the spectrum of Sun and another one named “Ziyanın Husülü” discussing the analysis of light.<sup>311</sup>

In order to mention briefly about the optical knowledge existing in the first journals of the Republic of Turkey, apart from the three articles mentioned above, Hüsni Hamid has an article named “Fizikteki Faraziyeler”. This article which was published in the Journal of İstanbul Darülfünun Faculty of Science (1924-1928) is a translation from Henri Poincare.<sup>312</sup> Also, there was another journal called Fen Alemi published in 1925-1926 which is the first popular scientific journal of Turkey. This journal includes, 5 articles of Mehmed Refik Bey and Kerim Erim Bey about the interpretation of Einstein’s theories and 3 articles of Ali Hikmet Bey about the new currents in physics, theories on light and chemical reactions. Apart from these, in the journal named Tabiat Alemi, published between 1925-1927 there exists an article named “Ziya mevceleri mi, mermileri mi?”. This article discusses the experiments occurring in the University of Chicago at that time to search for the nature of light whether it’s particle or wave.<sup>313</sup>

#### 4.4.3. Refik Fenmen’s Treatise *Madde ve Ziya* and the Introduction of Advanced Optics to Turkey

In the 1920s, the ambition of Mehmed Refik Fenmen (d. 1951) for the general relativity of Albert Einstein, his passionate defense on the theory led him to write the first book on this subject in Turkey and to introduce general relativity to Turkish Science. He wrote down his treatise *Einstein Nazariyesi: Mekan, Zaman ve Kütle Mevhumlarının Tebeddülü* in 1922 while he was teaching physics in Darülfünun and so Einstein’s general relativity was brought into country much earlier comparatively to other countries.<sup>314</sup> He also provided the general theory of relativity to be put into the schedule of Darülfünun and so the subject was handled in an academic level. Refik Fenmen has over than 30 treatises,

---

<sup>311</sup> Bahadır, pp. 41-46.

<sup>312</sup> Bahadır, s. 43.

<sup>313</sup> Bahadır, pp. 78-101.

<sup>314</sup> For example in France the general theory of relativity was highly criticized it was the latest country to adopt the theory among other countries. Therein, at the beginning of 1920s, except Paul Langevin the very close friend of Einstein, there were only one or two people who included the general theory of relativity in their schedules. For detailed information see, Meltem Akbaş, “Elektrik Mühendisi Refik Fenmen: Osmanlı’dan Cumhuriyet’e Yenilikçi Yorulmaz bir Aydın”, *Osmanlı Bilimi Araştırmaları*, Vol. 9, Issue 1-2, İstanbul 2008, pp. 101-118.

on subjects like physics, mathematics, electrical engineering, mechanical engineering in the form of popular science or as a course book. He also translated the treatise *La Nature de la lumière* of Max. Planck (1858-1947) published in Paris 1929 to Turkish as *Ziyanın Mahiyeti* with Dr. Kerim Bey. Hence, he also led the entrance of quantum mechanical phenomena to Turkey.<sup>315</sup> Refik Fenmen has another treatise named *Madde ve Ziya* published in 1937 that the importance of this treatise comes from its introduction of the advanced concepts of optics like photoelectric, diffraction, interference, wave-particle duality of light to Turkish Science. In this context, the examination of the treatise *Madde ve Ziya* of Refik Fenmen constitutes the conclusion of this study.

As Fenmen stated in the preface of his treatise, *Madde ve Ziya* was prepared by collecting the basic scientific views of H. Poincare, Einstein, L. De Broglie, Eddington, Langevin, Planck, Thibaud, Fabry and Boutaric. It consists of 10 sections and the first section is entitled as “New Ways of Scientific Thought”. This section discusses the revolutionary changes in the knowledge of matter and light and the reaction of scientists to these changes for the last 30 years according to the book (which refers to the beginning of 1900s). The second section is entitled as “What is Matter?” discussing the perception of matter developing since the antic ages. The third section is entitled as “The Granular Formation of the Electricity” and it mentions about; electrons which the writer called as “the atom of the electricity”, positrons which the writer called as “positive electrons”, protons and neutrons. The fourth section is on the lately developing quantum physics and the fifth section is on the constitution of the atom stating thoughts of scientists like Rutherford and Bohr. The sixth section is about the experiments for the transmutation of the matter and the studies of Crockfort, Walton and Curie are stated. The seventh section is entitled as “The Nature of Light” and will be given further thought for its introduction of new optical concepts. After this, fallowing sections are entitled as “The Materialization of the Energy, the Energisation of the Material” and “the Theory of Quantum Mechanics”. Finally the last chapter is entitled as “Philosophical Thoughts, Determinism” and a summary of the philosophical approaches developed in the light of these subjects is given.

The seventh section entitled as “The Nature of Light” begins with claiming that the statement of light is the most contradictive area of physics. Fenmen separates these contradictions into two basic categories as “particle and wave theories”. In the text, it’s

---

<sup>315</sup> Meltem Akbaş, “Einstein’ın Görelilik Teorisini Türkiye’ye Tanıtımlar (I) : Mehmet Refik Fenmen ve Kerim Erim”, *Osmanlı Bilimi Araştırmaları*, Vol. 4, Issue 2, Istanbul 2003, pp. 29-48.

firstly stated that Newton, the founder of classical mechanics, explored that small particles erupted from the light source to every direction with a speed of 300,000 km per second and it's stated that this claim existed over than a century. Later, it's discussed Huygen's disapproval of this claim. "Huygens didn't admit the speed of light in the form of wind speed as Newton did, instead he suggested that light expanded like the waves in water when a stone is thrown into it." In fact, to understand how the water molecules moved forming circles when a stone is thrown into a still water, a piece of cork on water should be tracked. This object, stays still not moving forward as the waves and moving up and down it becomes vertical to the spread of wave.<sup>316</sup>

Huygens claims that light waves propagate around a light source. According to him, just like waves being formed as the water rise and fall, light waves originate by a substance called aether present both in the space and in the mass of the objects. At this part of the text, Fresnel's contributions for this theory's improvement and Fresnel's claim that for the light waves' origination the aether should be vertical to the direction of propagation are stated. According to Fenmen, the nature of the aether in Huygens's theory of light remained indefinite. Fenmen also evaluates the negative completion of Michelson's experiment, which was done in order to measure the speed of the ground compared to the aether, as a big defeat for the supporters of the concept of aether.<sup>317</sup>

Fenmen continues to explain the phenomenon of interference which he defines as an inhibiting incident for Newton's corpuscular theory of light:

"When two light rays having same colors join each other on the same path, the intensity of the occurring incidents doesn't always increase; in fact, at some certain locations two light rays might weaken or annihilate each other. This incident called interference is explained in Huygen's theory by the overlapping of a wave trough and a wave crest of a light ray. Whereas, in Newton's theory, the annihilation of two wave particles moving in the same direction with the same speed can't be explained."<sup>318</sup>

Fenmen, continued stating Maxwell's exploration that the light waves are the same as the electromagnetic waves of a radio. "A vital point for the essential study of science of electricity" defined by Fenmen, the electromagnetic theory of Maxwell combines the incidents of light and electromagnetic. As for Hertz, he verified the conclusions of Maxwell with his experiments and he managed to pass the electromagnetic waves through the air by using no equipment. Fenmen continues; "This discovery of Hertz, led to the

---

<sup>316</sup> Refik Fenmen, *Madde ve Ziya*, Akba Kitapevi, Ankara 1940, pp. 54-55.

<sup>317</sup> Fenmen, p. 56.

<sup>318</sup> Fenmen, p. 57.

application of wireless telegraph, telephone and radio.” Fenmen defines the phrase wave length as the distance between the two successive wave crests or wave troughs and continues with Hertz. Hertz verified that the two kinds of waves which Maxwell suggested are the same kind, by testing a few meter long electromagnetic waves with some features of light as reflection, refraction and so forth.<sup>319</sup>

Fenmen states that there was no need for the presumed concept of aether anymore with light entering into the class of electromagnetic waves. According to Fenmen just when these progresses in science was going to end the disagreements between scientists, an exploration created trouble once again:

“This exploration is the phenomenon of photoelectric: In 1887, German physicist Hertz found out that, electrons with very high speed came out from a metal plate under the effect of ultraviolet light. Because of the fact that these electrons weren’t subjected to the state and the heat of matter, it was concluded that electrons gather their energies from the beams fallen into its surface instead of from the metal itself.”<sup>320</sup>

According to Fenmen, this exploration was a dash to Huygens’ theory. Rontgen rays and gamma rays emerging from radioactive matters were forming these incidents as well. Electrons were ejecting faster from the plate because these rays’ waves are shorter than ultraviolet lights’ waves.<sup>321</sup>

Fenmen continues: “These experiences show that absorbance of the energy of propagation does not occur continuously and this energy passes to electrons ejecting from the metal. The incidents’ independency of time shows that there needs to be an energy community in particular spots of the propagation through the metal.”<sup>322</sup> By this, Fenmen explains the background which led Einstein to explore the wave-particle duality of light and he introduces Einstein’s concept of photon:

“Einstein, under the influence of these ideas, to explain these incidents, he claimed in 1905 that the idea of light being in a corpuscular form should be adopted and he claimed that light consists of energy particles which he called as photons. He calculated the energy of these photons and found that, in accordance with quantum theory, it’s equal to the product of the constant  $h$  and the frequency of the light.”<sup>323</sup>

Fenmen continues with explaining the experiments and observations done for the photon theory. In the year 1915, an American Physicist named Millikan, performed experiments supporting the photon theory, hence Planck’s constant  $h$  is determined to be

---

<sup>319</sup> Fenmen, pp. 57-58.

<sup>320</sup> Fenmen, p. 60.

<sup>321</sup> Fenmen, pp. 60-61.

<sup>322</sup> Fenmen, p. 61.

<sup>323</sup> Fenmen, p. 61.

$h=6,55.10$  to 27. Photon theory is supported by Compton's experiments as well. As follows: "When a beam of light hits a matter, we know that it will both be reflected and penetrate into the matter with refraction."<sup>324</sup> Fenmen continues by explaining the Compton Scattering:

"Matter has an affection on light, similar to reflection, in which case, each particle of the matter plays a role independent from others: this is called the scattering of the light. From the position where the beam of light hits the object, lights emerge in every direction, electrons in the objects start vibrating with the energy taken from the ray. Each of them, becomes a source of propagation and this propagation preserves the same kind of wave as a general rule. However, when x-rays with short wave-length is interacted with carbon which has a small mass, there will be two propagations observed in the scattering: one with non changed wavelength like in a normal scattering, and the other with a longer wavelength."<sup>325</sup>

Fenmen states that this incident explored by A. H. Compton in the year 1922, couldn't be explained by the classical knowledge of physics. According to Fenmen, even if Compton theory strengthened the photon theory, the facts that it couldn't explain phenomena like scattering and that it revived Newton's theory which was left for a long time, caused lots of scientists to be unsatisfied from it. Fenmen states that only when Louis de Broglie's quantum mechanical theory ended the disagreements lasted for over than a century.<sup>326</sup>

---

<sup>324</sup> Fenmen, p. 61

<sup>325</sup> Fenmen, p. 62.

<sup>326</sup> Fenmen, pp. 62-63.

## 5. CONCLUSION

As a result of examining the optical knowledge between the years 1733-1937, signified as the process of the modern optical concepts' entrance to Ottoman Turkish Science, it could be said that the transmission of the optical knowledge didn't occur continuously and it propounded disconnections from time to time. The transmission initiated firstly as a result of military reasons and systematized by the engineering schools. A translation movement was begun and an extensive amount of Western treatises was translated into the Ottoman Language. One of the pioneers, Chief Instructor İshak Efendi, contributed a great deal to this movement not only because of his successive translations stated in this study but also his finding the Ottoman responses for each of the scientific terms instead of transferring them as they are. By this he contributed a great deal to the scientific terminology of the Ottoman language. His path is pursued by many Ottoman Scholars, both with the exegises to older texts and with further translations.

In the beginning of 1900s, Salih Zeki's studies raised the level of Ottoman Science a great amount for that he introduced the concepts of modern physics of the 19<sup>th</sup> century to Ottoman Turkey. The instutionalization of the education in Ottoman State and the establishment of the first universities led to the development of physics education by the means of Ottoman Universities. The treatises to be written down or the research to be actualized were determined according to the needs of these universities.

In 1930s a scholar of Darülfünun Refik Fenmen, who was "a reformist and inexhaustible intellectual" according to Meltem Akbaş, showed a special interest on the general theory of relativity of Albert Einstein. This interest of him not only introduced the general theory of relativity to Ottoman State but led to other examinations on modern physics. As a result of his extensive translations from the current scholars of Western Science, the concepts of modern optics were brought into the country. One example to this is his translation of *La Nature de la lumière* of Max Planck one of the founders of quantum mechanics to Turkish. On the other hand, he wrote down a treatise *Madde ve Ziya* by transferring the scientific views of Poincare, De Broglie, Eddington, Langevin, Thibaud, Fabry and Boutaric where he included the experiments of Marie Curie, Millikan and

Compton. Hence, Fenmen introduced the adventure of the nature of light that lasted for centuries and ended by the explanations of its wave-particle duality to Turkish Science.

## REFERENCES

1. Fenmen, Refik, *Madde ve Ziya*, Akba Bookstore, Ankara, 1940.
2. Ganot, A., *İlm-i Hikmet-i Tabiiye*, Antranik Kirçikyan (Trans.), Mekteb-i Tıbbiye-i Şahane Press, Istanbul, 1876.
3. Hodja Ishak Efendi, *Mecmua-i Ulum-i Riyaziye*, Amire Press, Istanbul, 1831.
4. Reynaud, Baron, *Traite Elementaire de Mathématique et de Physique*, Bachelier Press, Paris, 1839.
5. Zeki, Salih, “Mebhas-ı Ziya”, *Hikmet-i Tabiiye*, Kerabet Press, Istanbul, 1921.
6. Adıvar, Adnan, *Osmanlı Türklerinde İlim*, Remzi Bookstore, Istanbul, 1970.
7. Akbaş, Meltem “Einstein’ın Görelilik Teorisini Türkiye’ye Tanıtımlar (I) : Mehmet Refik Fenmen ve Kerim Erim”, *Osmanlı Bilimi Araştırmaları*, Vol. 4, No. 2, pp. 29-48, Istanbul, 2003.
8. Akbaş, Meltem, “Osmanlı ve Cumhuriyet Dönemi Modern Fizik Çalışmaları Üzerine bir Deneme”, *Türkiye Araştırmaları Literatür Dergisi*, Vol. 2, No. 4, pp. 153-162, Istanbul, 2004.
9. Akbaş, Meltem “Elektrik Mühendisi Refik Fenmen: Osmanlı’dan Cumhuriyet’e Yenilikçi Yorulmaz bir Aydın”, *Osmanlı Bilimi Araştırmaları*, Vol. 9, No. 1-2, pp. 101-118, Istanbul, 2008.
10. Akbaş, Meltem, *Osmanlı Türkiye’sinde Modern Fizik (19. Yüzyıl)*, PhD Thesis, Istanbul University the Institute of Social Sciences, 2008.

11. Akyüz, Yahya, *Osmanlı Son Döneminde Kızların Eğitimi ve Öğretmen Faika Ünlüler'in Yetiştirilmesi ve Meslek Hayatı*, 1999, [http://dhgm.meb.gov.tr/yayimlar/dergiler/Milli\\_Egitim\\_Dergisi/143/1.htm](http://dhgm.meb.gov.tr/yayimlar/dergiler/Milli_Egitim_Dergisi/143/1.htm), [Accessed June 2015].
12. Akgündüz, Seval Yinilmez, "Osmanlı Devleti'nde Okutulan İlk Fizik Kitabı: Usul-ü Hikmet-i Tabiiye" *Türk Tarih Eğitimi Journal*, Vol. 2, No.2, 2013.
13. Aydın, Mahir "Cezayirli Gazi Hasan Paşa", *Türk Diyanet Vakfı İslam Ansiklopedisi*, Vol. 7, Türkiye Diyanet Vakfı Press, pp. 501-503, İstanbul, 1993.
14. Aydüz, Salim, "Derviş Paşa (Kimyager)", *Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi*, Vol. 1, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
15. Aydüz, Salim "Hüseyin Rifkî (Tamani)", *Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi*, Vol. 1, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
16. Aydüz, Salim, "İshak Efendi (Hoca)", *Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi*, Vol. 1, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
17. Aydüz, Salim, "Mehmed Said Efendi (Müftizade-i Yenişehir)", *Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi*, Vol. 2, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
18. Bahadır, Osman, *Cumhuriyetin İlk Bilim Dergileri ve Modernleşme*, İzdüşüm Press, İstanbul, 2001.
19. Bell, A. E., *Christian Huygens and the Development of Science in the Seventeenth Century*, Edward Arnold Press, London, 1947.
20. Beydilli, Kemal, *Türk Bilim ve Matbaacılık Tarihinde Mühendishane, Mühendishane Matbaası Ve Kütüphanesi*, Eren Press, İstanbul, 1995.

21. Beydilli, Kemal “*Halil Hamid Paşa*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 15, Türkiye Diyanet Vakfı Press, pp. 316-318, İstanbul, 1997.
22. Beydilli, Kemal, “*Mustafa Paşa (Alemdar)*”, Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi, Vol. 2, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
23. Beydilli, Kemal, “*Kabakçı İsyanı*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 24, Türkiye Diyanet Vakfı Press, pp. 8-9, İstanbul, 2001.
24. Beydilli, Kemal “*Yaş Antlaşması*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 43, Türkiye Diyanet Vakfı Press, pp. 343-347, İstanbul, 2013.
25. Beydilli , Kemal “*Ziştovi Antlaşması*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 44, Türkiye Diyanet Vakfı Press, pp. 467-472, İstanbul, 2013.
26. Bos., H. J. M. “*Huygens, Christiaan*”, Dictionary of Scientific Biography, Vol. 6, Charles Scribner’s Sons Press, New York, 1981.
27. Cohen, I. B. “*Newton, Isaac*”, Dictionary of Scientific Biography, Charles Scribner’s Sons Press, New York, 1981.
28. Cohen, Morris, R., Drabkin, I. E., *A Source Book in Greek Science*, Harvard University Press, Boston, 1966.
29. Crombie, A. C. “*Grosseteste, Robert*”, Dictionary of Scientific Biography, Vol. 5, Charles Scribner’s Sons Press, New York, 1981.
30. Crombie, A. C. and J. D. North, “*Bacon, Roger*”, Dictionary of Scientific Biography, Vol. 1, Charles Scribner’s Sons Press, New York, 1981.
31. Çeçen, Kazım, “*Hüseyin Teyfik Paşa*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 19, Türkiye Diyanet Vakfı Press, pp. 14-15, İstanbul, 1999.

32. David, Geza, “*BARON de TOTT, François*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 5, Türkiye Diyanet Vakfı Press, pp. 83-84, İstanbul, 1992.
33. Dölen, Emre, “*Bilim-Fizik*”, Tanzimat’tan Cumhuriyet’e Türkiye Ansiklopedisi, Vol. 1, İletişim Press, İstanbul, 1985.
34. Dölen, Emre, “*Mühendislik Eğitimi*”, Tanzimat’tan Cumhuriyete Türkiye Ansiklopedisi, Vol. 5, İletişim Press, İstanbul, 1985.
35. Eastwood, Bruce S. “*Grimaldi, Francesco Maria* ”, Dictionary of Scientific Biography, Vol. 5, Charles Scribner’s Sons Press, New York, 1981.
36. Fazlıoğlu, İhsan, “*Seyyid Ali Paşa*”, Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi, Vol. 2, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
37. Fazlıoğlu, İhsan, “*İlm-i menâzir (Optik): Osmanlılar’da ilm-i menâzir*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 22, Türkiye Diyanet Vakfı Press, pp. 131-132, İstanbul, 2000.
38. Fazlıoğlu, İhsan, “*Mirim Çelebi*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 13, Türkiye Diyanet Vakfı Press, pp. 160-161, İstanbul, 2005.
39. Fazlıoğlu, İhsan, *Bilimin Osmanlıcası*, <http://www.ihsanfazlioglu.net/yayinlar/makaleler/1.php?id=47>, [Accessed June 2015].
40. Fazlıoğlu, İhsan, “XVIII. Yüzyıl Osmanlı Düşüncesinde Bunalım ve Arayış- II Felsefe-Bilim”, *Bilim ve Sanat Vakfı Journal*, No. 67, İstanbul, 2008.
41. Gingerich, Owen, “*Kepler, Johannes*”, Dictionary of Scientific Biography, Vol. 7, Charles Scribner’s Sons Press, New York, 1981.

42. Gölcük, Şerafettin and Metin Yurdağür, “*Gelenbevi*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 13, Türkiye Diyanet Vakfı Press, pp. 552-555, İstanbul, 1996.
43. Gören, Ahmet Kamil, “*Ahmed Emin (Servili)*”, Yapıtları ve Yaşamlarıyla Osmanlılar Ansiklopedisi, Vol. 1, Yapı Kredi Kültür Sanat Press, İstanbul, 1999.
44. Halaçoğlu, Ahmet, “*Humbaracı*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 18, Türkiye Diyanet Vakfı Press, pp. 349-350, İstanbul, 1998.
45. İhsanoğlu, Ekmeleddin, *Başhoca İshak Efendi, Türkiye’de Modern Bilimin Öncüsü*, Kültür Bakanlığı Press, Ankara, 1989.
46. İhsanoğlu, Ekmeleddin, “*İshak Efendi, Başhoca*”, Türk Diyanet Vakfı İslam Ansiklopedisi, Vol. 22, Türkiye Diyanet Vakfı Press, pp. 529-530, İstanbul, 2000.
47. İhsanoğlu, Ekmeleddin, *Osmanlılar ve Bilim, Kaynaklar Işığında Bir Keşif*, Nesil Press, İstanbul, 2003.
48. İhsanoğlu, Ekmeleddin (edit.), *Osmanlı Tabii ve Tatbiki Bilimler Literatürü Tarihi*, IRCICA press, Vol. 1,2. İstanbul, 2006.
49. İnönü, Erdal and Bahadır, Osman, *Türkiye’de Temel Bilimlerde İlk Araştırmacılar*, Büke Press, İstanbul, 2007.
50. Kaçar, Mustafa, “Osmanlı İmparatorluğu’nda İlk Mühendishanenin Kuruluşu”, *Toplumsal Tarih Journal*, No. 54, İstanbul, 1998.
51. Kaçar, Mustafa, *Osmanlı Devleti’nde Bilim ve Eğitim Anlayışındaki Değişmeler*, PhD Thesis, İstanbul University the Institute of Social Sciences, 1996.
52. Kaçar, Mustafa “Tersane Hendesehanesi’nden Bahriye Mektebi’ne Mühendishane-i Bahri-i Hümayun” *Osmanlı Bilimi Araştırmaları, Atilla Bir Armağanı*, Vol. IX, No. 1-2, 2007/2008, ed. Feza Günergün, İstanbul University Press. İstanbul, 2008.

53. Kazancıgil, Aykut, *Osmanlılarda Bilim ve Teknoloji*, Gazeteciler ve Yazarlar Vakfı Press, İstanbul, 1999.
54. Kazancıgil, Aykut “XIX. ve XX. yüzyıllarda Türkiye’de fizik ve tıbbi fizik tarihi ile ilgili yayınların notlu kaynakçası”, *Osmanlı Bilimi Araştırmaları*, Vol. 6, No. 2, pp. 320-323, İstanbul, 2004.
55. Keele , Kenneth D., “*Leonardo Da Vinci: Life, Scientific Methods and Anatomical Works*” Dictionary of Scientific Biography, Vol. 8, Charles Scribner’s Sons Press, New York, 1981.
56. Kocaman, Meltem, “Darüşşafakada Fizik Eğitiminin Başlangıcı”, *Osmanlı Bilimi Araştırmaları*, Vol. 14, No. 2, pp. 87-117, İstanbul, 2013.
57. Kopal, Zdenek, “*Römer, Ole Christansen*”, Dictionary of Scientific Biography, Vol. 11, Charles Scribner’s Sons Press, New York, 1981.
58. Lindberg, David C., *Theories of Vision From Al-Kindi to Kepler*, The University of Chicago Press, Chicago, 1976.
59. Lindberg, David C., “*Pecham, John*”, Dictionary of Scientific Biography, Vol. 10, Charles Scribner’s Sons Press, New York, 1981.
60. Lindberg, David C., “*Witelo*”, Dictionary of Scientific Biography, Vol. 14, Charles Scribner’s Sons Press, New York, 1981.
61. Lindberg, David C. “Alhazen’s Theory of Vision and Its Reception in the West”, *Studies in the History of Medieval Optics*, Variorum Reprints, London, 1983.
62. Lindberg, David C., “Al-Kindi’s Critique of Euclid’s Theory of Vision”, *Studies in the History of Medieval Optics*, Variorum Reprints, London, 1983.

63. Lindberg, David C., “The Intromission-Extramission Controversy in Islamic Visual Theory: Al-Kindi versus Avicenna”, *Studies in the History of Medieval Optics*, Variorum Reprints, London, 1983.
64. Lindberg, David C., “The Science of Optics”, *Studies in the History of Medieval Optics*, Variorum Reprints, London, 1983.
65. Lindberg, David C., “The Science of Optics”, *The Beginnings of Western Science*, The University of Chicago Press, Chicago, 1992.
66. Mahoney, Michael S., “Descartes: Mathematics and Physics”, *Dictionary of Scientific Biography*, Vol. 4, Charles Scribner’s Sons Press, New York, 1981.
67. Mahoney, Michael S., “Fermat, Pierre de”, *Dictionary of Scientific Biography*, Vol. 4, Charles Scribner’s Sons Press, New York, 1981.
68. Nasr, Seyyed Hossein, *Science and Civilization in Islam*, Islamic Texts Society Press, Cambridge, 1987.
69. Omar, Saleh Beshara, *Ibn al-Haytham’s Optics: A Study of the Origins of Experimental Science*, Bibliotheca Islamica Press, Minneapolis, 1977.
70. Özcan, Abdülkadir, “Humbaracı Ahmed Paşa”, *Türk Diyanet Vakfı İslam Ansiklopedisi*, Vol. 18, Türkiye Diyanet Vakfı Press, pp. 351-353, İstanbul, 1998.
71. Özcan, Abdülkadir, “Mehmed Tevfik Bey”, *Türk Diyanet Vakfı İslam Ansiklopedisi*, Vol. 28, Türkiye Diyanet Vakfı Press, pp. 536-537, İstanbul, 2003.
72. Özcan, Abdülkadir, “Patrona İsyanı”, *Türk Diyanet Vakfı İslam Ansiklopedisi*, Vol. 34, Türkiye Diyanet Vakfı Press, pp. 189-192, İstanbul, 2007.
73. Özcan, Abdülkadir, “Topal Osman Paşa”, *Türk Diyanet Vakfı İslam Ansiklopedisi*, Vol. 41, Türkiye Diyanet Vakfı Press, pp. 244-246, İstanbul, 2012.

74. Rashed, Roshdi, “*Geometrical Optics*”, Encyclopedia of the History of Arabic Science, Routledge Press, London, 1996.
75. Ronan , Colin A., *Dünya Kültürlerinde Bilimin Tarihi ve Gelişimi*, Trans: Ekmeleddin İhsanoğlu, Feza Günergun, Tubitak Press, Ankara, 2003.
76. Sabra, A. I., *Theories of Light from Descartes to Newton*, Oldbourne Press, London, 1967.
77. Sabra , A. I., “Ibn Al-Haytham”, Dictionary of Scientific Biography, Scribner Imprint, New York, 1981.
78. Sabra, A. I. “Ibn al-Haytham’s Lemmas for Solving ‘Alhazen’s Problem’.” *Archive for History of Exact Sciences*, No. 26, 1982
79. Sabra , A. I., *The Optics of Ibn al-Haytham. Book II, Introduction, Commentary, Glossaries, Concordance, Indices*, Warburg Institute, University of London, London, 1989.
80. Saliba, George, *Islamic Science and the Making of the European Renaissance*, MIT Press, Cambridge, 2007.
81. Struik, Dirk J., “*Snel, Willebrord*”, Dictionary of Scientific Biography, Charles Scribner’s Sons Press, vol. 12, New York, 1981.
82. Tekeli, Sevim, "Batılılaşmada son dönem: İshak Hoca", *Erdem*, vol. IV, No. 11, Ankara, 1998.
83. Topdemir, Hüseyin Gazi, *Takıyüddin’in Optik Kitabı, Işığın Niteliği ve Görmenin Oluşumu*, Turkish Republic Ministry of Culture Press, Ankara, 1999.

84. Topdemir, Hüseyin Gazi, “Modern Fiziğin Türkiye’ye Girişinde Baş Hoca İshak Efendinin *Mecmû‘a-i Ulûm-i Riyâziye* Adlı Çalışmasının Önemi”, Hasan Celal Güzel, Kemal Çiçek and Salim Koca (ed.), *TürklerJournal*, Vol. XVII, Ankara, 2002.
85. Topdemir, Hüseyin Gazi, *Modern Optiğin Kurucusu: İbnü’l-Heyssem, Hayatı, Eserleri ve Teorileri*, Atatürk Kültür Merkezi Başkanlığı Press, Ankara, 2002.
86. Topdemir, Hüseyin Gazi “Türk Fizik-Optik Tarihi Üzerine”, *Türkiye Araştırmaları Literatür Dergisi*, Vol. 2, No. 4, pp. 135-151, İstanbul, 2004.
87. Topdemir, Hüseyin Gazi, *Işığın Öyküsü*, Tübitak, Ankara, 2007.
88. Topdemir, Hüseyin Gazi, *İbn El-Heyssem ve Yeni Optik*, Lotus Press, Ankara, 2008.
89. Ulusoy, Çağatay, Enver Kartekin, *Yüksek Mühendis Okulu, Yüksek Mühendis ve Yüksek Mimar yetiştiren müesseselerin tarihi*, İstanbul Teknik University Library Press, İstanbul, 1958.
90. Wallace, William A. “*Albertus Magnus*”, *Dictionary of Scientific Biography*, Charles Scribner’s Sons Press, vol. 1, New York, 1981.
91. Yayın Kurulu, “*Hüseyin Paşa (Küçük)*”, YYOAA, Vol. 1, Yapı Kredi Kültür Sanat Yayıncılık, İstanbul, 1999.
92. Zorlu, Tuncay and Burak Barutçu, Atilla Bir, C. Ozan Ceyhan and Aras Neftçi, *İstanbul Teknik Üniversitesi ve Mühendislik Tarihimiz*, İstanbul Technical University Press, İstanbul, 2012.





