CULMINATION OF THE MOON AS TRUE NORTH DETERMINANT AND ITS APPLICATION IN QIBLA DIRECTION

UNDERGRADUATE THESIS

Submitted to Faculty of Sharia and Law

In Partial Fulfilment of the Requirement for Undergraduate Degree

In Islamic Law

by:

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2020

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MOTTO

قَدْ نَرٰى تَقَلُّبَ وَجْهِكَ فِى السَّمَآءِ ۚ فَلَنُوَلِّيَنَّكَ قِبْلَةً تَرْضٰىهَا ۖ فَوَلِّ وَجْهَكَ شَطْرَ
الْمَسْجِدِ الْحَرَامِ ۗ وَحَيْثُ مَا كُنْتُمْ فَوَلُّوْا وُجُوْهَكُمْ شَطْرَهٗ ۗ وَاِنَّ الَّذِيْنَ اُوْتُوا الْكِتٰبَ
لَيَعْلَمُوْنَ اَنَّهُ الْحَقُّ مِنْ رَّبِّهِمْ ۗ وَمَا اللّٰهُ بِغَافِلٍ عَمَّا يَعْمَلُوْنَ

(البقرة : ١٤٤)

"We see the turning your face (for guidance) to the heaven; Now shall We turn thee to a Qibla that shall please thee. Turn then thy face in the direction of the Sacred Mosque; wherever ye are, turn your faces in that direction. The people of the Book know well that this is the truth from their Lord, nor Allah is unmindful of what they do."

(Al-Baqarah: 144)[1]

[1] Yusuf Ali, *The Holy Quran English Translation of The Meanings and Commentary*, (Medina, Saudi Arabia: King Fahd Printing Complex), 1991, 58-59.

DEDICATION

All the praises and thanks be to Allah, the Lord of the world

This Thesis is dedicated to:

My dear parents; Mohamad Kheroni and Hartini

Love and respect are always for you. Thank you for the valuable efforts and contributions in making my education success.

My beloved brother and sister; Mohamad Rifqi Sabilul Haq, Mohamad Muttaqizzaky A Hafidz and Reeha Aisyiyah Al Khoironiyah, you are the most beautiful present I've ever had.

My thesis supervisors; Dr. H. Ahmad Izzuddin, M. Ag. and Moh. Khasan, M.Ag., who give their time to teach and guide me

My classmates, CahBe 2016

Who colored my college life with many unforgettable moments

Those people who appreciate and encourage this thesis

DECLARATION

I declare that this thesis is definitely my own work, I am completely responsible for content of this thesis. Other writer's opinions of findings included in the thesis are quoted or cited in accordance with ethical standards.

Semarang, October 23, 2020

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…ssunnah Al Khoiron

NIM: 1602046041

TRANSLITERATION

I. Single Consonant

Arabic	Written	Arabic	Written
ة	B	ط	ṭ
ت	T	ظ	ẓ
ث	Th	ع	ʿ
ج	J	غ	Gh
ح	ḥ	ف	F
خ	Kh	ق	Q
د	D	ك	K
ذ	Dh	ه	L
ر	R	ً	M
ز	Z	ن	N
س	S	و	W
ش	Sh	ه	H
ص	ṣ	ء	ʾ
ض	ḍ	ي	Y

II. DOUBLE CONSONANT

Double consonant, including *syaddah*, is written in double. For example:

رَبَّكَ is written *rabbaka*

الحَدُّ is written *al haddu*

III. Vowel

1. Short vowel

Vowel or *harakat fathah* is written as *a*, *kasrah* as *I*, and *dammah* as *u*.

2. Long vowel

Long vowel (māddah), which in arabic uses harakat and hurûf, is written as hurûf and stipe (-) above it: ā, ī, ū. For example:

قال is written as *qāla*

قيل is written as *qīla*

يقول is written as *yaqūlu*

3. Double vowel

- *Fathah+ya' sukun* is written ai

  For example: كيف is written as *kaifa*

- *Fathah+wawu sukun* is written as au

  For example: حول is writen as *haula*

IV. Ta' Marbūṭah (ة) in the End of Word

1. Ta' Marbūṭah (ة) in the end of word with *sukūn* is written as *h,* except Arabic word that is used as Indonesian word, such as *salat, zakat, tobat,* etc.

For example:

طلحة is written as *ṭalḥah*

التوبة is written as *al-taubah*

2. Ta' Marbūṭah (ة) that is followed by (ة ال) if they are separated or read as *sukun*, it must be written as *h*

For example:

روضة الاطفال is written as *rauḍah al-aṭfāl*

But if they are read a unit, it must be written as *t.*

For example:

روضة الاطفال is written *rauḍatul aṭfāl*

V. Article Alif+Lam (ال)

1. Article(ال) that is followed by *huruf syamsiyah* is written as how it is read and separated by stripe (-).

For example:

الرحيم is written as *ar-Raḥīmu*

السيد is written as *as-sayyidu*

الشمس is written as *asy-syamsu*

2. Article (ال)that is followed by *huruf qamariyah* is written as *al* and separated by stripe (-).

For example:

الملك is written as *al-Maliku*

الكافرون is written as *al-kāfirūn*

VI. Word as Part of Phrase or Sentence

1. If the structure or words does not change the way to read it, it is then separately each word, or
2. If the structure of words changes the way to read it and unites them, then it must be written as the way it is read, or separated in the structure. For example: خير الرازقين is written as *khair rāziqīn or khairurrāziqīn.*

ABSTRACT

Moon is the closest celestial object to the Earth as it is 384,400 km (238,828 miles) far from the Earth. Because of its distance, the Moon has been affecting the life in the Earth. The Moon's presence helps stabilize the planet's wobble, which helps stabilize the climate. It also causes tides, creating a rhythm that has guided humans for thousands of years. The Moon has many functions that hasn't been explored further, the Moon might be used to determine the true north. In determining the Qibla direction, the calculation of the direction is by using the nearest path through the great circle. If there are three great circles on the surface of a sphere intersect each other, it will create a spherical triangle. the three points formed are the angles A, B, and C. the angle A is used to mark a certain location that needs to be determined the direction of the Qibla, angle B represents the Kaaba, while the C angle represents the North pole position or the true north. There are some methods of determining true north. There are observing of the pole star, using theodolite, using compass, and using the gnomon to cast shadow when the Sun is culminating. Since the Moon is bright enough to make objects on Earth cast shadows, it is possible to shift the method of the Sun's culmination to the Moon to determine the true north.

This research aims to find the implementation of using the Moon's culmination to determine the true north. The result is to find whether this method can be used as a reference for determining true north or not and how accurate is it then the result can be applied in determining the Qibla direction. This research is the qualitative research and is a field research. Primary data is taken from direct observations and calculation data of true north direction using culmination of the Moon. While the secondary data from library research sourced from journals, books about the Moon and the Qibla direction, paper, and GPS. This research is used two methods of collecting data; field observation and documentation.

This research found that the method in determining true north using the Moon's culmination is the same as the method using the Sun's. The difference is that the Moon's culmination method uses the Moon when it is transiting in the meridian as the main reference. There are two formulas in determining the Moon's culmination time. the first is by transforming the Moon upper mer. pass. data provided in the Nautical Almanac to the local time. the second is by manual calculation using the ephemeris data. The calculation and the observation show that the observation of Moon's culmination can be conducted at the Moon age 10 until 20 or when the Moon stars to enter the gibbous phase. Meanwhile, the best time is when the Moon is in the full Moon phase and a day before and after full Moon. And after the observation, the result shows that the Moon's culmination method has slight deviation with the Sun's method and shows the Moon's culmination method can be used as a reference for determining the true north and applied to determine the Qibla direction or for other observation related to *'Ilm Falak* or Astronomy discussion.

Keywords: *Moon's culmination, true north, qibla direction*

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corrected my writing in English, gave knowledges and always supported me to finish my thesis.

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Semarang, October 23, 2020

<u>Muhamad Fiqhussunnah Al Khoiron</u>
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CHAPTER I

INTRODUCTION

A. Background of Study

Moon is the closest celestial object to the Earth, its mean distance to Earth is 384,400 km (238,828 miles). The closest distance to Earth is 356,410 km or 221,438 miles. This closest distance is called perigee. and when the Moon and Earth reach the greatest distance it can reach 406,697 km or 252.681 miles. [1] The Moon is also the only natural satellite oh the Earth, held in orbit around it by force of gravity.[2]

As the Moon is the closest object to the Earth, it has affected the life in the Earth. The Moon's presence helps stabilize our planet's wobble, which helps stabilize our climate. It also causes tides, creating a rhythm that has guided humans for thousands of years.

A graduate thesis written by Muhammad Farid Azmi "Kulminasi Bulan Sebagai Acuan Titik Koordinat Bumi untuk Penentuan Arah Kiblat" found that the Moon when it is culminating can be used to determine the longitude and the latitude of certain place. It is also mentioned that the culmination of the Moon can be used to know the true north. In this research, it is mentioned the steps to determine the true north with the culmination of the Moon whose

[1] Sir Patrick Moore (ed), *Phillip's Atlas of the Universe,* revised edition, (London: Octopus Publishing Group, Ltd.), 2005, 43.

[2] Giles Sparrow, *Moon: Exploring the Solar System,* (Singapore: Brown Partworks Limited), 2001, 6.

process is a shift from the Sun's culmination method.[3] However, this thesis does not explain further about the field practice and the accuracy of this method, because the focus of his study is the determination of the coordinates of the Earth with the culmination of the Moon and not the determination of the true north.

True north is an important component of Astronomy discussion. The determination of true north usually relates to the observational astronomy. Observational astronomy or practical astronomy is one of the scopes of Astronomy besides theoretical astronomy which discusses the calculations to determine the position of celestial bodies.[4] One type of practical astronomy is Islamic Astronomy or Falak.[5] There are two object of studies that are closely related to the true north in Islamic Astronomy, namely: the determining of Qibla direction and observation of the new Moon or *Hilal*.[6]

In the observation of New Moon, true north is used as a reference to determine the azimuth of the Sun and Moon. In term, azimuth means an arc of the horizon measured between a fixed point (such as true north) and the vertical circle passing through the centre of an object usually in astronomy and

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[3] Muhammad Farid Azmi, "Kulminasi Bulan sebagai Acuan Titik Koordinat Bumi untuk Penentuan Arah Kiblat," *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2019), 102, unpublished.

[4] Ahmad Izzuddin, *Ilmu Falak Praktis,* (Semarang: Pustaka Rizki Putra, 2012), 3.

[5] *'Ilm Falak* or Islamic Astronomy is a branch of Astronomy that object of its study is related to Islamic worship. There are four objects of Islamic Astronomy studies, namely: prayer times calculation, Qibla direction, *Rukyatul Hilal* or Observation of New Moon, and calculation of solar and lunar eclipse. See Nur Hidayatullah al-Banjary, *Penemu Ilmu Falak: Pandangan Kitab Suci dan Peradaban Dunia,* (Yogyakarta: Pustaka Ilmu, 2013), 1.

[6] The Moon crescent that can be seen right after the Sunset the day of the *ijtima'* (conjunction between the Sun and the Moon). See Muhyiddin Khazin, *Kamus Ilmu Falak,* (Yogyakarta: Buana Pustaka, 2005), 30.

navigation clockwise from the north point through 360 degrees.[7] From that definition, it can be concluded that determining azimuth of celestial bodies such as Sun and Moon in practice need to determine the true north as the first step.

The determining of true north is also needed in the Qibla direction determination. To determine the Qibla precisely and accurately, it is necessary to determine the true north direction to facilitate the determination of the Qibla azimuth.[8] Qibla azimuth means a circular arc calculated from north to east in a clockwise direction to the projection of the Kaaba at the Great Mosque in Mecca.[9]

In determining the direction of Qibla, the accuracy of the results must be considered. It is because facing Qibla is one of the conditions should be fulfilled in prayers and the other Islamic worships. If one ignores this condition, their prayer is invalid. As explained in Qs. Al-Baqarah Verse 144

قَدْ نَرٰى تَقَلُّبَ وَجْهِكَ فِى السَّمَآءِ ۚ فَلَنُوَلِّيَنَّكَ قِبْلَةً تَرْضٰىهَا ۖ فَوَلِّ وَجْهَكَ شَطْرَ الْمَسْجِدِ الْحَرَامِ ۗ وَحَيْثُ مَا كُنْتُمْ فَوَلُّوْا وُجُوْهَكُمْ شَطْرَهٗ ۗ وَاِنَّ الَّذِيْنَ اُوْتُوا الْكِتٰبَ لَيَعْلَمُوْنَ اَنَّهُ الْحَقُّ مِنْ رَّبِّهِمْ ۗ وَمَا اللّٰهُ بِغَافِلٍ عَمَّا يَعْمَلُوْنَ

"We see the turning your face (for guidance) to the heaven; Now shall We turn thee to a Qibla that shall please thee. Turn then thy face in the direction of the Sacred Mosque; wherever ye are, turn your faces in that direction. The people

[7] Merriam-Webster, "Azimuth", https://www.merriam-webster.com/dictionary/azimuth, accessed on 4 February 2020.
[8] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis,* (Semarang: Walisongo Press, 2010), 45.
[9] Slamet Hambali, *Ilmu Falak: Arah Kiblat Setiap Saat,* (Yogyakarta: Pustaka Ilmu, 2012), 22.

of the Book know well that this is the truth from their Lord, nor Allah is unmindful of what they do." (QS. Al-Baqarah: 144)[10]

Through this verse, Allah conveyed the Prophet Muhammad that Allah had known the Prophet's wishes or prayers that the Qibla which was originally in the Bait al-Maqdis be transferred to the Kaaba. It is intended that the Muslims face in the same direction that is the Ka'ba at the Great Mosque (Masjid al-Haram).

The hadith narrated by Imam Al-Bukhari also explained the important role of Qibla direction in prayer.

حَدَّثنَا عَمْرُو بْنُ عَبَّاسٍ قَالَ: حَدَّثنَا ابْنُ الْمَهْدِيِّ قَالَ: حَدَّثنَا مَنْصُوْرُ بْنُ سَعْدٍ عَنْ مَيْمُوْنِ بْنِ سِيَاهٍ، عَنْ أَنَسٍ بْنِ مَالِكٍ، قَلَ: قَالَ رَسُوْلُ اللهِ ﷺ:(مَنْ صَلَّى صَلَاتَنَا وَاسْتَقْبَلَ قِبْلَتَنَا وَأَكَلَ ذَبِيْحَتَنَا فَذَلِكَ الْمُسْلِمُ الَّذِى لَهُ ذِمَّةُ اللهِ وَذِمَّةُ رَسُوْلِهِ فَلَا تُخْفِرُوا اللهَ فِى ذِمَّتِهِ)[11] (رواه البخارى)

"Amr bin Abbas related to us from Ibnu al-Mahdi from Manshur bin Sa'd, from Maimun bin Siyah, narrated 'Anas bin Malik: Allah's Messenger (pbuh) said, "Whoever prays like us and faces our Qibla and eats our slaughtered animals is a Muslim and is under Allah's and His Apostle's protection. So do not betray Allah by betraying those who are in His protection." (Sahih Al-Bukhari)

To determine the true north, there are some methods. The first is by using constellations. Constellations are groups of stars that have almost the same shape and look close together.[12] By using certain constellations, the cardinal

[10] Yusuf Ali, *The Holy Quran English Translation of The Meanings and Commentary*, 58-59.

[11] Abi Abdillah Muhammad Ibni Ismail al Bukhari, *Shahih Al Bukhari Juz al Awal*, (Istanbul: Daar Al Fikr, 2005), 102.

[12] Slamet Hambali, *Ilmu Falak 1: Penentuan Awal Waktu Shalat & Arah Kiblat Seluruh Dunia*, (Semarang: Program Pascasarjana IAIN Walisongo Semarang), 227

direction can be determined at a certain place. One of the constellations that can show the north is the Ursa Major and Ursa Minor constellations or often called the Polar or Polaris constellations.[13]

The next method is by using compass.[14] This method can be used to determine the direction but not recommended to determine the true north. It's because the measurement results of compass are still affected by the Earth's magnetic field. It must be known that the true north is a direction that is coincident with a meridian, and points to the geographical North Pole through the Earth's axis. It is also called the geographic north.[15] While the measurement result of compass direction is called the magnetic north.

Another method to determine the true north is by using gnomon or *istiwa'*[16] by utilizing the phenomenon of the culmination[17] of the Sun in the meridian. Gnomon is very related to the Sun because its function is to capture shadows and providing information about the height of the Sun.[18] This is the best and most ancient astronomical instrument used by ancient people to observe the sun's shadows. [19] This concept is only can be used in daylight by

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[13] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis,* 46.

[14] Compass is a navigation tool to determine direction, there is a magnetic needle that always points towards the North-South. See: Muhyiddin Khazin, *Kamus Ilmu Falak,* 31

[15] Juanico Meliton, *Physical Geography,* (Quezon City: JMC Press, 1987), 59.

[16] *Istiwa'* a stick that is plugged perpendicular to a flat plane and placed in a place that is not blocked by anything to produce shadows from the sun, this kind of stick is known as Gnomon. See Susiknan Azhari, *Ensiklopedi Hisab Rukyat,* (Yogyakarta: Pustaka Pelajar, 2005), 80.

[17] Culmination is the position of the Sun when its center is right on the meridian, so that at that time the shadows will stretch right in the north-south direction. See A. Jamil, *Ilmu Falak Teori & Praktik Arah Qiblat, Awal Waktu dan Awal Tahun Hisab Kontemporer*, (Jakarta: Amzah 2009), 33.

[18] Anisah Budiwati, "Tongkat Istiwa', Global Positioning System (GPS) dan Google Earth untuk Menentukan Titik Koordinat Bumi dan Aplikasinya dalam Penentuan Arah Kiblat", Journa; *Al-Ahkam,* Vol. 26, No 1, April 2016, 70.

[19] Martin Isler, "An Ancient Method of Finding and Extending Direction", *Journal of the American Research Center in Egypt Vol. 26,* (1989), https://www.jstor.org/stable/40000707,

setting a gnomon on a flat plane that has been given a circle. Then doing observation on the sun's shadow before and after culmination. After finding the intersection point of the Sun's shadow with the circle before and after culmination, we can get the East-West direction. The true North or North-East direction can be shown by making intersection line of the East-West direction.

Inspired by the culmination of Sun method, using culmination of the Moon probably could be the alternative method to determine the true north. The Moon does not radiate its own light, but the Moon's surface reflects the Sun's rays. The half surface of the Moon will always shine because of the Sun's rays while the half facing away from the Sun will be dark.[20] Since the Moon is bright enough to make objects on Earth cast shadows when it is in the full moon phase, it might be possible to use gnomon as night astronomical instruments just as it used during the day. One of which is determining true north when the Moon is transiting. However, this observation is probably not every day can be conducted because the phases of the moon are different every day.

On this basis, the author is interested in examining this method as one of the development methods of determining the true north direction so that it can add to the treasures of Islamic Astronomy in the field of determining the Qibla direction. Sourced from these things, the authors conducted a thesis research with the title "Culmination of The Moon as True North Determinant and Its Application in Qibla Direction".

[20] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedy,* (London: Octopus Publishing Group), 2002, 269

B. Research Questions

The research will be formulated into some main problems in the following form of several questions below:

1. How is the method of the culmination of the Moon as true north determinant?
2. How is the accuracy of the culmination of the Moon as true north determinant and its application in Qibla Direction determination?

C. Objective of Study

Objectives dealing with the problem statement, the following objectives were expected to cover:

1. To explain the method of the culmination of the Moon true north determinant
2. To show the accuracy of the culmination of the Moon as true north determinant and the application in Qibla Direction.

D. Significance of Study

This study was expected to give contribution on Indonesia Islamic Astronomy to enrich knowledge about the determination of the true north by using the culmination of the Moon. This also could give benefits to students and people generally that can become a referral source for further research.

E. Literature Review

Through literature review, the writer knows the previous researches that the object of discussion is related to the research conducted by the writer. The purpose is not only to inform which research, but also to avoid plagiarism. The writer has not found a specific and detailed research that discusses the method of determining true north by using the culmination of the Moon and or its application to the Qibla direction. But there are some researches that are relevant to the topic of this research.

Muhammad Farid Azmi with his graduate thesis *Kulminasi Bulan sebagai Acuan Titik Koordinat Bumi untuk Penentuan Arah Kiblat*.[21] This research shows that coordinate point could be determine by culmination of the Moon. This method was a shift of the culmination of the Sun. The formulation of latitude calculation uses the same method of culmination of the Sun, but uses the Moon as the source data instead the Sun. While the calculation of longitude uses system called Local Apparent Lunar Time. It is when the moon intersects with the local meridian considered as 12 o'clock. The result of this research shows the small value of deviation in the coordinate point determination using culmination of the Moon. Deviations for latitude are in range of 5,64" to 5' 19,22" and for longitude of the place the deviations between 13,49" to 9'

[21] Muhammad Farid Azmi, "Kulminasi Bulan sebagai Acuan Titik Koordinat Bumi untuk Penentuan Arah Kiblat", unpublished.

20,47”. This research also showed the step to determine true north using culmination of the Moon but in not in specific explanation.

Alvian Meydiananda with his undergraduate thesis *Uji Akurasi Azimuth Bulan sebagai Acuan Penentuan Arah Kiblat.* [22] This research says about the implementation of azimuth of the Moon in the determining of Qibla direction. Azimuth of the Moon is an arc measured from the North to East point clockwise through the horizon up to the Moon's projection. By using theodolite, this method can be used to determine Qibla direction on the 4th to the 25th of lunar time, while the ideal time is on the 11th to 19th or when the Moon’s shape approaches the full circle.

Lukman with his undergraduate thesis *Studi Analisis Rashdul Kiblat Bulan dalam Kitab Jami’u Al-Adillah Karya KH. Ahmad Ghozali.*[23] This research explains about KH Ahmad Ghozali’s thought on the Qibla direction determination using *rashdul Qibla* of the Moon in *Kitaab Jami’u al-Adillah. Rashdul Qibla* occurs when the azimuth of celestial bodies intersects with the Qibla direction line somewhere. To test its accuracy, this study compared the results of determining the Qibla using the Moon with the Sun's rashdul Qibla and there was a tendency towards Qibla of around 40' (minutes).

[22] Alvian Meydiananda, “Uji Akurasi Azimuth Bulan sebagai Acuan Penentuan Arah Kiblat” *Undergraduate Thesis* IAIN Walisongo Semarang (Semarang, 2012), unpublished

[23] Lukman, “Studi Analisis Rashdul Kiblat Bulan dalam Kitab Jami’u Al-Adillah Karya KH. Ahmad Ghozali” *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2016), unpublished

Mohamad Akyas with his undergraduate thesis *Susanne M. Hoffmann Discourse on Observing the Moon.*[24] This research says about Susanne M. Hoffmann discourse related observing the moon and to know her suggestion to repeat Al-Biruni observation on measuring the distance between two cities. The result of the research is that Susanne M. Hofmann discourse in observing the moon is divided into two lines. The first is related to the poor condition of the sky in Semarang, she recommended to still do Rukyatul hilal. Second, about the lunar eclipse, in accordance with the field, she mastered the history of Science. Susanne M. Hoffmann was succeeding to repeat the Al-Biruni observation in measuring the distance of two cities by the lunar eclipse.

F. Research Methodology

Methodology is the researcher guidance to discover the purpose of this research. In this research, the writer uses the following research methods:

1. Type of Research

The type of this research is qualitative research.[25] The writer tries to understand and explain the concept of true north determination using the culmination of the Moon as the object of the discussion. This research is also classified as field research.[26] The research is conducted by direct

[24] Mohamad Akyas, "Susanne M. Hoffmann Discourse on Observing the Moon", *undergraduate thesis* UIN Walisongo Semarang (Semarang, 2018), unpublished.

[25] Qualitative analysis basically emphasizes more on the deductive and inductive processes as well as on the analysis of the dynamics between observed phenomena, using scientific logic. See Syaifuddin Azwar, *Metode Penelitian,* (Yogyakarta: Pustaka Pelajar, 2004), 5.

[26] Field research is research conducted directly in the field or respondents. See M. Iqbal Hasan, *Pokok-pokok Metodologi Penelitian dan Aplikasinya*, (Bogor: Ghalia Indonesia, 2002), 11.

observation to obtain the accuracy data of true north using the culmination of the Moon which is then applied to determine Qibla direction by using instruments such as gnomon (*istiwa'*) and theodolites.

2. **Sources of Data**

According to the source, the research data is classified into two data, primary data and secondary data.[27]

a. Primary Data

Primary data or firsthand data is data obtained directly from the research object. Primary data of this study are data obtained from observations and calculation data of true north direction using culmination of the Moon.

b. Secondary Data

Secondary data or second-hand data is data that is not directly obtained by researchers from the object of research. The writer gets this data from library research sourced from journals, books that discuss the Moon and the Qibla direction, paper, data from software such as GPS[28] and Google Earth, sources from archives, dictionaries, encyclopedias, internet and books related to this research as supplementary data from the author's research.

[27] M. Iqbal Hasan, "Pokok – Pokok Metodologi Penelitian dan Aplikasinya", (Bogor: Ghalia Indonesia, 2002), 82.

[28] Global Positioning System (GPS) is a system of direction guidance (navigation) that utilizes satellite technology. See Slamet Hambali, *Ilmu Falak 1*, 230.

3. Method of collecting data

To obtain the data needed in this research, the writer uses three data collection methods.

a. Field Observation

Field observation is a data collection technique through observation of research objects to obtain facts in the field. The writer makes direct observation of true north produced by the culmination of the Moon and record the observation as a source of data based on natural setting in the field.

b. Documentation

The documentation study is carried out by collecting and examining documents that relevant to the research study, such as scientific journals, books, articles related to the concept of determining the true north with the culmination of the Moon, the determination of Qibla direction and supporting data during field research such as the Moon data at the time of observation and the coordinates of the observation site.

4. Data Analysis Methods

The author will collect data obtained from the results of field studies, documentation and interviews, then analyze the data. This analysis was carried out from before entering the field, when in the field, and after completion in the field to obtain conclusions on the theories, methods, and accuracy of true north direction with the culmination of the Moon. [29]

G. Systematic of Writing

To achieve the purpose of this research, the writer organized this thesis by the systematic of writing with 5 chapters based on the second model of writing of a qualitative method in "*Pedoman Penulisan Skripsi Program Sarjana Fakultas Syari'ah dan Hukum Uin Walisongo Semarang"* which puts the research methodology in chapter (1) in term to get efficiency and effectiveness in the thesis writing.[30]

CHAPTER I INTRODUCTION

It contains the background of the research, statements of the problem, objectives of the study, significances of study, the preview of the literature, research methodology, and thesis organization.

CHAPTER II TRUE NORTH AND QIBLA DIRECTION

On chapter II, the writer will discuss the basic theory used in this thesis such as the definition of true north, different types of north, the true north in determining the Qibla direction, and the existing method to find the true north.

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[29] Prof. Dr. Sugiyono, *Metodologi Penelitian Kuantitatif, Kualitatif dan R&D,* (Bandung: Alfabeta, 2017), cet. Ke-25, 245

[30] Fakultas Syariah UIN Walisongo, *Pedoman Penulisan Skripsi Program Sarjana Fakultas Syariah UIN Walisongo Semarang*, (Semarang: Fakultas Syari'ah UIN Walisongo, 2019), 46

CHAPTER III USING MOON'S CULMINATION IN DETERMINING TRUE NORTH

On this chapter, the writer explains about the Moon, the phases of the moon, the definition of culmination of the Moon, manual calculation of culmination of the Moon, the use of data in calculating the culmination of the Moon, and the procedure in determining the true north using the Moon's culmination.

CHAPTER IV THE ANALYSIS OF THE ACCURACY OF USING MOON'S CULMINATION IN DETERMINING TRUE NORTH AND THE APPLICATION IN DETERMINING QIBLA DIRECTION

On this chapter, the writer will state the main subject of discussion of this thesis. It is analysis of the accuracy of the culmination of the Moon method to determine true north and the application of this method to determine the Qibla direction.

CHAPTER V CLOSING

In this chapter contains the conclusion of the study and the result of the research which the writer analyses, the advice, and the closing line.

CHAPTER II

THE TRUE NORTH AND THE QIBLA

A. Understanding the True North

1. The Definition of True North

North is one of the cardinal directions or the four main points of a compass. The other cardinal directions are South, East, and West. These four directions are also known as cardinal points and written by their first letters: N, S, E, and W.[1]

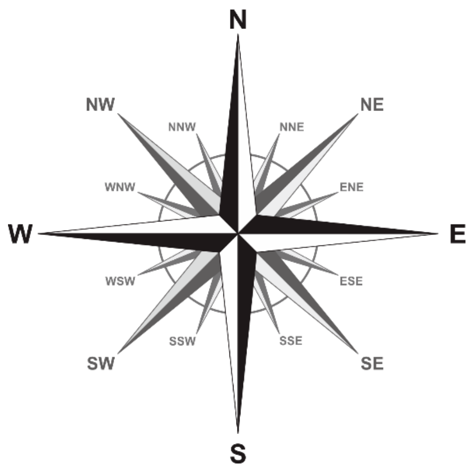

Figure 2.1 Compass points
(source: private document)

Besides cardinal directions, there are also ordinals directions that refer to the direction found at the point equally between each cardinal direction. Ordinal directions are also known as intercardinal directions. An intercardinal direction is named and formed by ordinal points that surround

[1] Caitlin Dempsey, "Cardinal Directions and Ordinal Directions", in *Geographiyrealm* (Geography 101, July 22, 2013) https://www.geographyrealm.com/cardinal-directions-ordinal-directions/#:~:text=Cardinal%20directions%20are%20the%20four,using%20the%20word%20%E2%80%9Cdue%E2%80%9D. accessed on July 27, 2020.

it. for example, the middle point between N and E is NE (North East). Ordinal directions are: northeast (NE), southeast (SE), southwest (SW), and northwest (NW).[2] there are also directions midway between each cardinal and ordinal direction referred to as secondary-intercardinal directions. Examples of secondary-intercardinal directions are: NNW, NNE, and ENE.

When working with a map or a compass, north point is always on the top. It happens because north refers to the direction to the North Pole from any point on the surface of the Earth. This is basically the definition of True North. The true north always points to the north pole. It is because the true north is calculated by using an imaginary line through the Earth rather than by using a compass.[3]

True north is also called geographic north.[4] The Earth rotates on the geographic north and south poles. The geographic north and south poles are where lines of longitude (meridians) converge in the north.

The true north and south are important instruments in geographic direction. the reference system usually employed in geographic direction is the latitude-longitude coordinate system with meridians converging on the North and South Poles and lines of latitude running parallel to the

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[2] Henry William Jeans, *Navigation and Nautical Astronomy*, third edition, (London: Oxford University, 1876), 20

[3] Merriam-Webster, “True North”, https://www.merriam-webster.com/dictionary/true%20north, accessed on July 13, 2020.

[4] Susiknan Azhari, *Ensiklopedi Hisab Rukyat*, p. 219

equator.[5] The North Pole is located in the middle of the Arctic Ocean. While the South Pole lies on a continental land mass known as Antarctica.[6] In this system, the latitude is measured in degrees north or south of the equator with the degree values are between 0° and 90° in north and 0° and -90° in south. The latitude reaches a maximum at the north poles and south poles.

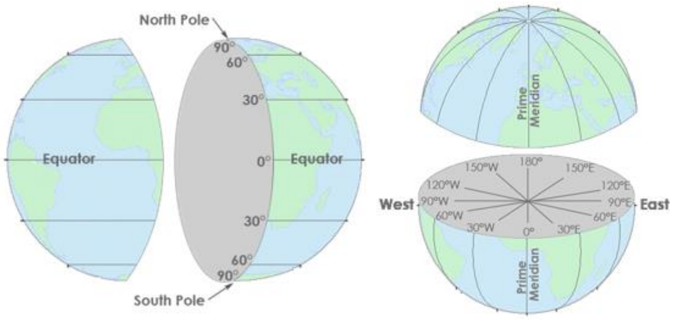

Figure 2.2 latitude-longitude coordinate system with the geographical north *(north pole) and south as the maximum degrees of latitude* *(source: https://gisgeography.com/)*

2. The Different types of North

The discussion above explains that true north of geographic north refers to the north pole in the middle of the Arctic Ocean. Besides true north, there are also another types of north. Magnetic north refers to the measurement of direction by using a compass. The magnetic needle of compass seldom points to the north pole and deflects to the east or west of the true north. It happens because the direction gained from the compass is still affected by the Earth's magnetic field.[7] The deflection is called the

[5] R.W. McCOLL, *Encyclopedia of World Geography*, first edition, (United States of America: Golson Books, Ltd.) 281.

[6] GIS Geography, "Magnetic North vs Geographic (True) North Pole", https://gisgeography.com/magnetic-north-vs-geographic-true-pole/, accessed on July 27, 2020

[7] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis*, 46

variation of the compass and is different in various places, and is also subject to a slow change in the same place.[8]

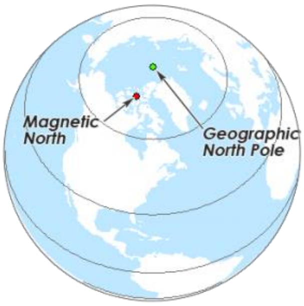

Figure 2.3 Magnetic North and Geographic North
(source: https://gisgeography.com/)

The Earth's magnetic field is not stable. The changes happen incessantly. Among others, the magnetic poles move from year to year. Magnetic pole can be defined as the point on the earth's surface at which the dip needle takes a vertical position, or as the point where the horizontal intensity of the earth's magnetic field becomes zero.[9] Over the last 150 years, the magnetic pole has crept north over 1000 kilometres. Scientists suggest it migrates about 10 kilometres per year and can even flip from pole-to-pole.[10]

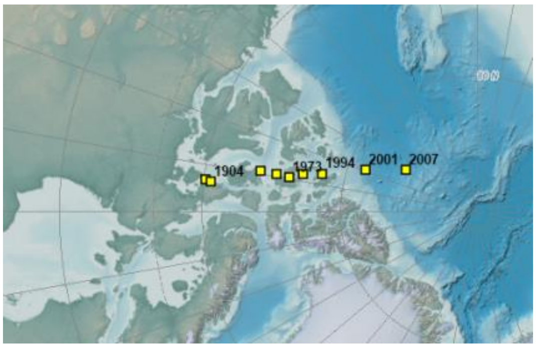

Figure 2.4 magnetic north pole shifts
(source: https://maps.ngdc.noaa.gov/viewers/historical_declination/)

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[8] Henry William Jeans, *Navigation and Nautical Astronomy,* 30

[9] Sir Harold Spencer Jones, Sc. D., F. R. S., "The Positions of The Magnetic Poles", *The Polar Record*, Vol. 5, No. 35-36, January-July 1948, (Cambridge, Scott Polar Institute), 148

[10] GIS Geography, "Magnetic North vs Geographic (True) North Pole", https://gisgeography.com/magnetic-north-vs-geographic-true-pole/, accessed on July 27, 2020

Another type of north is the grid north. Grid means a network of uniformly spaced horizontal and perpendicular lines (as for locating points on a map).[11] While the grid north means the direction of north that is established by using the vertical grid lines based on a map.[12] For a simple definition, the grid north is the north that appears in a map. It is usually illustrated by placing the letters "GN" on a vertical line in the marginal information.

The grid north allows to use the UTM grid lines on map as the north reference. UTM means Universal Transverse Mercator System, an overlay system used by the National Geospatial Intelligence Agency (NGIA) to divide the entire Earth into 60 sectors, running from 84 ° North to 80 ° South, and 6 ° wide each.[13]

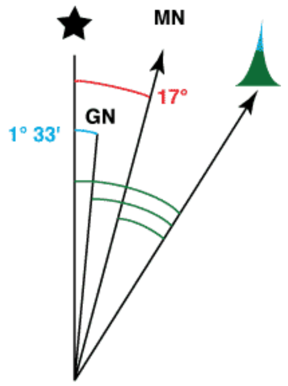

Figure 2.5 The grid north
(source: https://gisgeography.com/)

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[11] Merriam-Webster, "Grid", https://www.merriam-webster.com/dictionary/grid, accessed on August 30, 2020.

[12] Pearson Custom Publishing, *Geography, Map Skills and Environmental Awareness*, second custom edition for JROTC, (United State of America: Pearson Custom Publishing), 2005, 27.

[13] James H. Zumberge, et.al, *Physical Geology*, (New York: Mc Graw-Hill Companies), 2007, 71.

The picture above shows that there is different between the true north, the magnetic north, and the grid north. The star symbol on the picture shows the true north direction, while the letter "MN" refers to the magnetic north. These three types of north can be different in any place on Earth surface. The difference between these three north directions needs to be known so that there are no errors in reading the directions on the map.[14]

B. True North in Determining the Qibla Direction

1. The Definition of Qibla

The word "qibla", etymologically, comes from Arabic "قبلة". It is a *maṣdar* (gerund/verbal noun) of the verb "قبل-يقبل-قبلة" which means to face.[15] This word has the same definition as the word *"jihah"* or *"syaṭrah"* which means the direction in which we face.[16] In Indonesia dictionary (Kamus Besar Bahasa Indonesia) the word qibla (Indonesia: *kiblat*) is defined as: 1) *Arah ke Kakbah di Mekah pada waktu salat* (direction to the Kaaba in Mecca during prayer time), 2) *Arah* (direction); *jurusan* (way); *mata angin* (points of compass).[17] Similar to this definition, Merriam-

[14] Gunawan Admiranto, *Menjelajahi Tata Surya*, (Yogyakarta: Kanisius), 2009, 19.

[15] Warson Munawwir, *al-munawwir Kamus Arab–Indonesia*, (Surabaya: Pustaka Progresif), 1997, 1087-1088.

[16] Departemen Agama RI, *Pedoman penentuan arah kiblat*, Direktorat Jenderal Pembinaan Kelembagaan Agama Islam, Direktorat Pembinaan Badan Peradilan Agama Islam, 1994/1995, p. 10

[17] KBBI Daring, "Kiblat", Badan Pengembangan dan Pembinaan Bahasa, Kementerian Pendidikan dan Kebudayaan Republik Indonesia. https://kbbi.kemdikbud.go.id/entri/kiblat. Accessed on August 19, 2020.

Webster dictionary defines qibla as the direction of the Kaaba shrine in Mecca toward which all Muslims turn in ritual prayer.[18]

From those all definitions, it can be seen that the Qibla literally means the Kaaba physically located in Mecca. In the book "Menentukan Arah Kiblat Praktis (*Determining Practically the Qibla Direction*)", Ahmad Izzuddin also stated that the Qibla is the Kaaba or at least the Great Mosque of Mecca (*al-Masjid al-Ḥarām*) by considering the latitude and longitude.[19] It is because the Kaaba is the place where Muslims face during prayer times. While the Qibla direction means the direction wherever people can face the Kaaba.

Some of scholars and scientists have their opinion in understanding The Qibla definition terminologically. KH. Slamet Hambali stated in his book, *Ilmu Falak I*, that the Qibla direction is the direction to the Kaaba (Mecca) through the nearest route where every Muslim must face that direction in ritual prayer.[20] The word “the nearest route” means the closest distance through the great circle to the Kaaba. It is similar to the definition of Qibla direction stated by Muhyiddin Khazin. He wrote in his book that the Qibla direction is the closest distance or direction along the great circle that passes through the Kaaba (Mecca) from a particular location in a

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[18] Merriam-Webster, “Qibla”, https://www.merriam-webster.com/dictionary/qibla, accessed on August 19, 2020.

[19] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis*, 4

[20] Slamet Hambali, *Ilmu Falak 1: Penentuan Awal Waktu Shalat & Arah Kiblat Seluruh Dunia*, 84

city.[21] Ahmad Izzuddin also defines the Qibla direction as facing the direction of the Kaaba or at least the Great Mosque of Mecca by considering the direction and the closest position calculated from a specified area.[22]

From all those definitions above, it can be concluded that the Qibla direction means is the direction to the Kaaba by calculate the closest path seen from a certain place on the Earth surface. So that facing the Qibla considers the nearest path through the Great circle.

2. The Importance of True North Determination in the Qibla Direction

Facing the Qibla is an obligation to all Muslims when they turn in ritual prayer. It is because facing Qibla is one of the conditions should be fulfilled in prayers and the other Islamic worships. If one ignores this condition, their prayer is invalid. As explained in Qs. Al-Baqarah Verse 144.

قَدْ نَرٰى تَقَلُّبَ وَجْهِكَ فِى السَّمَاۤءِۚ فَلَنُوَلِّيَنَّكَ قِبْلَةً تَرْضٰىهَا ۖ فَوَلِّ وَجْهَكَ شَطْرَ
الْمَسْجِدِ الْحَرَامِ ۗ وَحَيْثُ مَا كُنْتُمْ فَوَلُّوْا وُجُوْهَكُمْ شَطْرَهٗ ۗ وَاِنَّ الَّذِيْنَ اُوْتُوا
الْكِتٰبَ لَيَعْلَمُوْنَ اَنَّهُ الْحَقُّ مِنْ رَّبِّهِمْ ۗ وَمَا اللّٰهُ بِغَافِلٍ عَمَّا يَعْمَلُوْنَ

"We see the turning your face (for guidance) to the heaven; Now shall We turn thee to a Qibla that shall please thee. Turn then thy face in the direction of the Sacred Mosque; wherever ye are, turn your faces in that

[21] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktik*, first ed, (Yogyakarta: Buna Pustaka, 2004), 50.

[22] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis,* 4

direction. The people of the Book know well that this is the truth from their Lord, nor Allah is unmindful of what they do." (Al-Baqarah: 144)[23]

Through this verse, Allah conveyed the Prophet Muhammad that Allah had known the Prophet's wishes or prayers that the Qibla which was originally in the Bait al-Maqdis be transferred to the Kaaba. It is intended that the Muslims face in the same direction that is the Kaaba at the Great Mosque.

Muhyiddin Khazin stated that the main point of the Qibla is about the direction, specifically the direction of the Kaaba in Mecca. The direction of the Kaaba can be determined from any point or place on the Earth's surface by doing calculations and measurements.[24] Therefore, the calculation of the Qibla direction is basically a calculation to find out which direction through the Kaaba in Mecca is seen from somewhere on the Earth's surface. So, that all movements of Muslims who are praying, whether standing, bowing, or prostrating always coincide with the direction that leads to the Kaaba.

The first generation of Muslims were not in trouble while finding the Qibla direction, because they were close to the Kaaba or Mecca. They simply used the direction of the pilgrim road to Mecca or the cardinal directions.[25] Then after centuries, after Islam spread throughout the world, the calculation of the Qibla direction is by using the nearest path through

[23] Yusuf Ali, *The Holy Quran English Translation of The Meanings and Commentary*, 58-59.

[24] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktik*, 50.

[25] David A. King, *Islamic Astronomy,* in "Astronomy before The Telescope", (London, British Museum Press), 1996, 159-160.

the great circle. Earth shape is globe.[26] The study explains that a globe or sphere geometry consists of great circle and small circle and arc on the surface. Great circle is a circle centered at the center of the globe. It means that the center of the great circle is the same as the center of the globe. The center of the globe is defined as a point with equal distance to the entire surface.[27] Meanwhile, If the plane does not contain the center of the sphere, its intersection with the sphere is a small circle. The globe has many large circles, including the circles of longitude and the equator. One of the small circles on the globe is the latitude circle.[28]

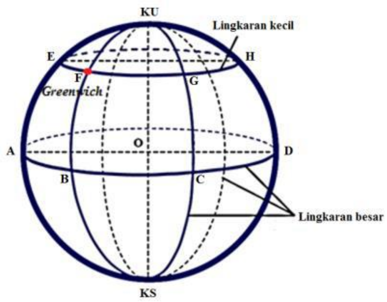

Figure 2.6 The great circle and the small circle on Earth's surface

The great circle becomes the reference for the spherical trigonometry theory. This is the commonly used theory in the Qibla direction determination. In this theory, if there are three great circles on the surface of a sphere intersect each other, it will create a spherical triangle. the three points formed are the angles A, B, and C.[29] In determining the Qibla

[26] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedy,* (London: Octopus Publishing Group), 2002, 121.

[27] Luthfi Adnan Muzamil, *Studi Falak dan Trigonometri: Cara Cepat Dan Praktis Memahami Trigonometri Dalam Ilmu Falak,* (Yogyakarta: Pustaka Ilmu), 2015, 43.

[28] Suci Novira Aditani, Dyah Fitriana Masithoh, Nonoh Siti Aminah, "Penentuan Arah Kiblat dengan Metode Segitiga Bola", *Prosiding Seminar Nasional Fisika dan Pendidikan Fisika (SNFPF),* Vol. 6, No. 1, 2015, 36.

[29] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis,* 26.

direction, those three angles represent the coordinates of certain place. Usually the angle A is used to mark a certain location that needs to be determined the direction of the Qibla, angle B represents the Kaaba, while the C angle represents the North pole position or the true north.

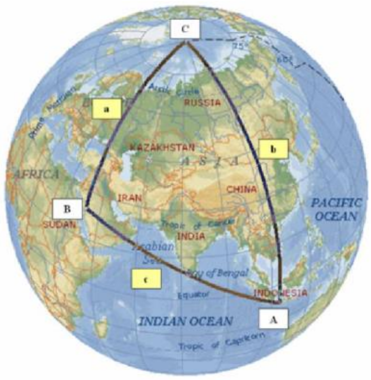

Figure 2.7 three great circles formed a spherical triangle with specified angles (ABC)

The Qibla direction determination is about to find the number of A angle. The A angle is calculated from the B point or the true north through the circle to the C point (Kaaba). This angle is also called azimuth. Azimuth is defined as Angular distance of an object measured westwards around the horizon from due north at 0º, through due east at 90º, due south at 180º and so on.[30] For example, in Indonesia, the azimuth of the Qibla is between 292º -296º. It means that the direction of the Qibla in Indonesia is Indonesia faces between the west and the north.[31] From the explanation above, it shows that the true north is needed in the spherical triangle calculation and is an important instrument in determining Qibla direction.

[30] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedy,* 44.

[31] Ahsin Dinal Mustafa, "Qibla Directions through Ulama's Fatwa: Comparative Study between Qibla Direction Fatwa of Indonesian Ulama Counciland Dar Al-Ifta Al-Misriyyah", *Al-Hilal: Journal of Islamic Astronomy,* Vol. 1, No. 1. October 2019. 118.

C. The Existing Methods of Determining True North

There are some methods of determining true north. Either classic or modern methods have been used to determine true north. Further explanation of the method of determining the true north is described below.

1. Shadow cast by the Sun

A study found that the ancient Egyptian surveyors had ability to orient some of their monuments to meridian. Generally, their temples were not well placed, but some of pyramids, especially the Great Pyramid, were oriented almost precisely to the geographical north.[32] Martin Isle believes that the Egyptian surveyors oriented the pyramids by using the movements of the Sun.

With an instrument called gnomon, people can easily track the Sun movements based on its shadow to determine the true north. Gnomon or *istiwa'* is a stick that is plugged perpendicular to a flat plane and placed in a place that is not blocked by anything to produce shadows from the sun.[33]

At equal times before and after apparent noon (Sun's culmination) the shadows thrown by pole would be of equal length. This method is applied by setting the gnomon the center of circle. A few minutes before culmination a mark is made at the end of the shadow cast by the pole then

[32] Martin Isler, "An Ancient Method of Finding and Extending Direction", *Journal of the American Research Center in Egypt Vol. 26*, (1989), https://www.jstor.org/stable/40000707

[33] Susiknan Azhari, *Ensiklopedi Hisab Rukyat*, 80.

making a mark after the culmination with radius equal to the previous mark.[34]

the true East-West line can be created after finding the intersection point of the Sun's shadow with the circle before and after culmination. The true North or North-East direction can be shown by making intersection line of the true East-West direction.[35]

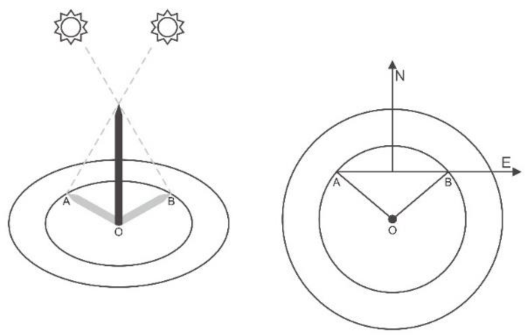

Figure 2.8 Using gnomon to determine the true north

This method uses the Sun’s shadow as the main instrument and only used in the daylight. What if this method changed the Moon as the main instrument instead of the Sun? Moon also cast clear shadow when it is in full phase. This is what the writer tries to proof and will be explained in the next chapter.

2. Observation of the Pole Star

The Pole star or Polaris is a star in a constellation called Ursa Minor that located 1°15’ from the north pole and moves in a circle around it. Another star known as Elioth, in Ursa Major, comes into the meridian on

[34] Arnold Lupton, *A Practical Treastise on Mine Surveying,* third edition, (London: Longmans, Green, and Co.), 1901, 356-357.
[35] Ahmad Izzuddin, *Ilmu Falak Praktis,* 42-43.

its right ascension about half an hour before the pole star reaches the meridian on its lower transit.[36] Thus if the Pole star is connected with a line until the Alioth, it will obtain an approximate line to the true north.[37]

3. Theodolite

Theodolite is a tool used to determine the altitude and azimuth of a celestial body. This tool has two axes, a vertical axis to see the altitude or height scale of celestial bodies and a horizontal axis to see the azimuth scale. The axes help the binoculars used to target celestial bodies can move freely in all directions.[38]

Theodolite is considered the most accurate instrument in determining the true north. By referring to the movement of celestial bodies, and the help of GPS satellites, theodolites can show a position up to units of arc seconds (1/3600).[39] The way to use theodolite is to target a celestial object such as the Sun. the Sun is easier to target than other celestial objects to determine the true north because of its light can easily captured by theodolite lens.

4. Using Compass

It has been discussed above that compass is inaccurate. The magnetic needle of the compass seldom points to the north pole. It is because the direction gained from the compass is still affected by the

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[36] Arnold Lupton, *A Practical Treastise on Mine Surveying,* 362

[37] Ahmad Izzuddin, *Ilmu Falak Praktis,* 46

[38] Susiknan Azhari, *Ilmu Falak: Teori dan Praktek*, first edition, (Yogyakarta: Lazuardi), 2001, 216.

[39] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis,* 55.

Earth's magnetic field. The corrections are sometimes necessary when using a compass to determine the direction.[40]

Depending on where the compass is located on the surface of the Earth the angle between true north and magnetic north, called magnetic declination can vary widely with geographic location. In Indonesia, the magnetic declination or variation is between -10 and +4,50 depending on the location.[41] Not only the magnetic variation, the amount of iron located around the compass can also affects the magnetic needle of compass.[42]

[40] Henry William Jeans, *Navigation and Nautical Astronomy,* 30.
[41] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis*, 48.
[42] Henry William Jeans, *Navigation and Nautical Astronomy,* 31.

CHAPTER III

USING MOON'S CULMINATION IN DETERMINING TRUE NORTH

A. The Moon and the Movements of the Moon

Moon comes from the Latin "luna" which is then often referred to as "lunar". Moon is the Earth's only natural satellite, held in orbit around Earth by the force of gravity[1].[2] Although the Moon is pulled by Earth's gravitation, it will not fall to Earth due to the centrifugal force[3] arising from its orbit around the Earth. The centrifugal force of the Moon is slightly larger than the gravitational force between the Earth and the Moon. It causes the Moon's distance is increasing at a rate of 3,8 centimeters (1.5 inches) per year away from Earth.

The origin of the Moon is uncertain. The old theory that told the Moon simply broke away from the Earth, leaving the hollow now filled by the Pacific Ocean, has long been discounted. A theory explains that Earth and the Moon were formed together from the solar nebula, but there is also theory with high supports explains that Moon was created due to a collision between the Earth

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[1] Gravity is the force by which a planet or other body draws objects toward its center. The name of gravity came from the Latin word for weight, *gravitas*. The force of gravity keeps the Moon orbits around the Earth. See R.W. McColl (ed), *Encyclopedia of World geography,* first edition, (New York: Fact on File inc.) 2005, 660-661

[2] Giles Sparrow, *Moon: Exploring the Solar System,* (Singapore: Brown Partworks Limited), 2001, 6.

[3] Centrifugal force is an apparent force that appears when an object is forced to move along a circular or curved path. The force is actually the result of the inertia of the object attempting to keep the object moving in a straight line. See: Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedy,* 80.

and a large wandering body. The thing that can be believed is the analyses of the lunar rocks show that the Moon and the Earth are of about the same age.[4]

LUNAR DATA[5]	
Distance from Earth, center to center:	
Max. (apogee)	406,697 km (252.681 miles)
Mean	384,400 km (238,828 miles)
Min. (perigee)	356,410 km (221,438 miles)
Orbital period	27.321661 days
Axial rotation period	27.321661 days
Synodic period	29d 12h 44m 3s
Mean orbital velocity	3680 km/h (2286 miles/h)
Orbital inclination	5° 9’
Apparent diameter	max. 33’ 31” mean 31’ 6” min. 29’ 22”
Density, water = 1	3.34
Mass, Earth = 1	0.012
Volume, Earth = 1	0.020
Escape velocity	2.38 km/s (1.48 miles/s)
Surface gravity, Earth = 1	0.165
Albedo	0.07
Mean magnitude at Full	-12.7
Diameter	3476.6 km (2160 miles)

Table 3.1 Lunar data

The Moon orbits the Earth in an ellipse, a shape that looks like a circle. Because the Moon follows its elliptical orbit, it varies from distance to Earth. The closest distance to Earth is 356,410 km or 221,438 miles. This closest distance is called perigee. and when the Moon and Earth reach the greatest distance it can reach 406,697 km or 252.681 miles. this phenomenon is also called apogee.[6]

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[4] Sir Patrick Moore (ed), *Phillip’s Atlas of the Universe,* revised edition, (London: Octopus Publishing Group, Ltd.), 2005, 42.

[5] *Ibid*, 43.

[6] Jajak, *Astronomi Ilmu Pengetahuan Luar Angkasa*, (Jakarta: Harapan Baru Raya), 2006, 65.

The Moon goes round the Earth, it also moves rotates on its axis just like the other celestial objects. The Moon's movements can be explained below:

1. **Moon's Rotation**

   The moon rotates on its axis with a period of 27 1/3 days (27.321661 days). The rotational motion of the Moon is retrograde (the Moon moves in counterclockwise or west to east).[7] The Moon's axial rotation period is equal to its orbital period. It means that in one move around the Earth, the Moon only makes one rotation. This is why only one surface of the Moon is always visible from Earth, while the other surfaces of the Moon are never visible.[8] This is due to tidal friction over the ages. During its early history, the Moon was much closer to the Earth than it is now, and the Earth's rotation period was shorter, while the Moon is being driven outwards from the Earth.[9]

2. **Moon's Revolution**

   The Moon rotates in an orbit just like the explanation above. The movement of the Moon around its orbit is called revolution.[10] The revolution of the Moon towards Earth occurs because the Moon is a natural satellite of the Earth, like most satellites, the motion of the Moon's revolution is elliptical and circles the Earth.

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[7] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 342.

[8] Slamet Hambali, *Pengantar Ilmu Falak: Menyimak Proses Pembentukan Alam Semesta,* (Yogyakarta: Bismillah Publisher), 2012, 217.

[9] Sir Patrick Moore (ed), *Phillip's Atlas of the Universe,* 42.

[10] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 342.

There are two periods involved with the orbit of the Moon around the Earth. The synodic period or the interval between one Moon phase and the next is 29.5 days (29d 12h 44m 3s).[11] This period has a lot of influence on human life, especially in determining a Lunar-based calendar.[12]

Another Moon's period is the sidereal period. Sidereal period means the time it takes a planet or moon to move from a position back to the same position relative to the stars, as viewed from the Sun.[13] refer to the Moon, sidereal period means the time it takes the Moon to complete one revolution around Earth. The moon takes 27.321661 days to rotate 360° around the Earth.

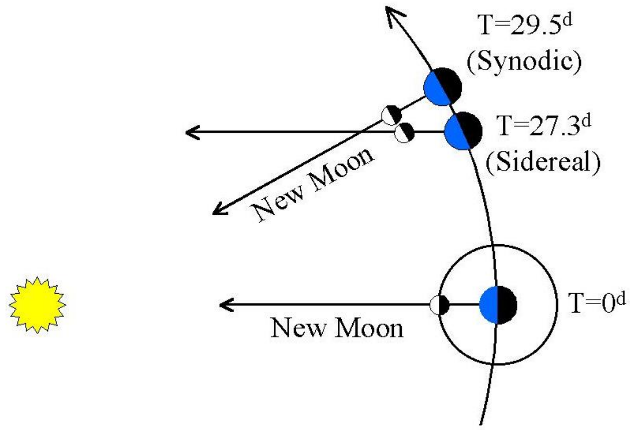

Figure 3.1 Synodic and sidereal period of Moon (https://community.dur.ac.uk/john.lucey/users/lunar_sid_syn.html)

3. Moon Phase

The Moon does not radiate its own light, but the Moon's surface reflects the Sun's rays. The half surface of the Moon will always shine

[11] *Ibid*, 42

[12] Slamet Hambali, *Pengantar Ilmu Falak*, 217.

[13] Linda K. Glover, *National Geographic Encyclopedia of Space*, (Washington D.C.: National Geographic), 2005, 31.

because of the Sun's rays while the half facing away from the Sun will be dark. The half-moon face is always facing to the earth due the sidereal rotation period of 27.3 days equal to revolution of 27.3.[14] As the Moon orbits the Earth, it is seen to go through a sequence of phases as the proportion of the illuminated hemisphere visible from Earth changes. The position of the Moon, the Sun and the Earth makes a gradual change on Moon-phase.[15]

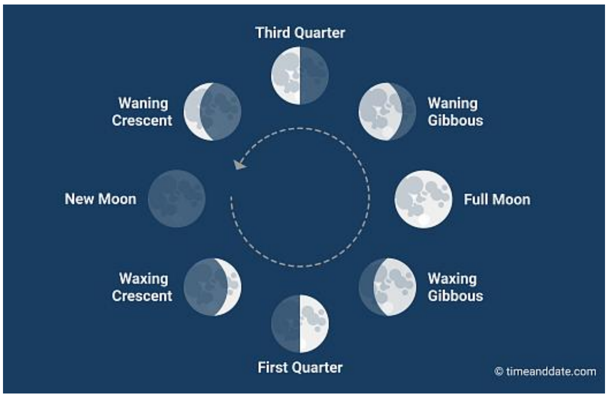

Figure 3.2 The phases of the Moon
(https://www.timeanddate.com/astronomy/moon/phases.html)

Four importance Moon-phases are conjunction[16], first quarter, full moon and last quarter. When the Moon is between the Sun and the Earth, the side facing the Earth is dark. This phase is called the new moon.[17] When Moon in the crescent stage, the dark side of the Moon may often be seen shining faintly. It due to light reflected on the Moon from the

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[14] Moedji Raharto and Novi Sopwan, "A Study the length of Synodic Periods of Several Lunar Calendar in Indonesia", *Prosiding Seminar Astronomi dalam Budaya Nusantara*, Yogyakarta, 25 Mei 2015, 1.

[15] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 269

[16] Conjunction is the alignment of two bodies in the solar system so that they have the same celestial longitude as seen from Earth, in this case the conjunction happens between the Moon and the Sun. see Joseph A. Angelo, Jr., *Encyclopedia of space and astronomy*, (New York, Fact of File, inc.), 2006, 141

[17] Linda K. Glover, *National Geographic Encyclopedia of Space,* 141

Earth and is known as earthshine.[18] A week later the Moon moves and the half the visible side is sunlit. This is the first quarter. The next week, Moon is opposite the Sun and enters the full moon phase.[19] At new moon or full moon phase, eclipses can occur. When the Moon completes its sequence or phase from a new moon to the next it is called lunation.[20]

4. **Moon's daily motion**

The Moon moves eastward on its orbit (Earth) at the rate of about 13° per day, as a result of this motion the time of Moonrise, Moonset, and meridian passage occur about 51 minutes later (on the average) each day.[21] As for the position of the Sun, the Moon also moves at the rate about 12° per day. This means that every hour, the Moon moves longer than the daily motion of the Sun by half (½) an arc or as wide as the Sun disk or the Moon disk itself.[22]

The Moon's orbit is inclined at angle about 5°08' to the plane of the Earth's orbit. When these two planes' line of intersection rotates in a similar manner in every 19 years (approximately), the phases of the Moon will recur on the same day of the year. This is called the Metonic cycle. Therefore, the Moon's maximum declination varies form 28° 35' (23°27'+5°08') to 18° 19' (23°27'-5°08') according to the relative

[18] Sir Patrick Moore (ed), *Phillip's Atlas of the Universe,* 42.
[19] Giles Sparrow, *Moon: Exploring the Solar System,* 8.
[20] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 269
[21] George L. Hosmer, *Textbook on Practical Astronomy,* first edition, (New York: John Wiley & Sons), 1910, 143.
[22] Slamet Hambali, *Pengantar Ilmu Falak,* 224.

position of the plane of the moon's orbit and the plane of the equator.[23] This causes the Moon to move sideways every day depending on its declination value.

5. **Moon's Physical Libration**

The half surface of the Moon observing from the Earth will always shine because of the Sun's rays. However, the actual center point of the visible disc of the Moon is not always the same, it always changes slightly from its original location. Both the north pole and south pole of the Moon always appear alternately. This is called the libration. Libration also means the small oscillation of a celestial body about its mean position, but the term of libration is used most frequently to mean the Moon's libration. As a result of Moon's libration it is possible to see, at different times, 59% of the Moon's surface.[24]

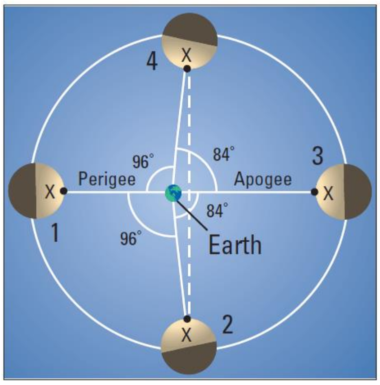


Figure 3.3 Moon's libration in longitude
(source: Sir Patrick Moore, Phillip's Atlas of the Universe)

There are three kinds of Moon libration, the first is libration in longitude. As explained before, the Moon rotates the Earth as its orbit in

[23] George L. Hosmer, *Textbook on Practical Astronomy*, 141-142.
[24] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 227.

elliptical rather than circular and it moves in its fastest when its closest to the Earth (as shown in the figure 3.3). However, the rate of axial rotation does not change, so that the position in orbit and the amount of axial spin become periodically out of step.[25] As a result, at times a little more of the lunar surface is visible at the eastern or western limb than when the Moon is at its mean position. The period of this libration can be calculated in linear first order theory and it is shown that the longitude libration has a period of 2.9 years.[26]

The next libration is libration in latitude. This libration happens because the Moon's equator is tilted slightly around 5 degrees from its orbital plane.[27] This causes the north and south poles of the Moon to appear alternately after the Moon has travelled half its path around the Earth, while, the visible disc center point will be different, shifted up or down. this libration is retrograde with a period near 81 years.[28]

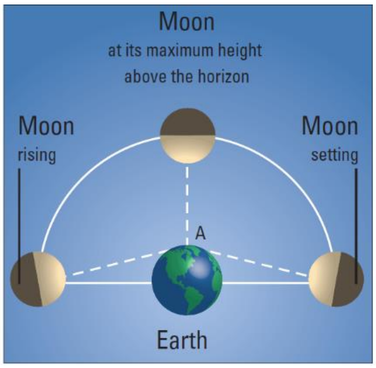


Figure 3.4 Moon's diurnal or daily libration
(souce: Sir Patrick Moore, Phillip's Atlas of the Universe)

[25] Sir Patrick Moore (ed), *Phillip's Atlas of Universe,* 47-48.

[26] N. Rambaux, J. G. Williams, "The Moon's Physical Librations and Determination of Their Free Modes", *Celestial Mechanics and Dynamical Astronomy*, Springer Verlag, 2010, 109 (1), 85-100.

[27] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 227.

[28] N. Rambaux, J. G. Williams, *The Moon's Physical Librations and Determination of Their Free Modes,* 85-100.

The last libration is diurnal or daily libration. This libration is caused by which the Earth's rotation allows to see more of the Moon's surface at its western limb when it is rising, and more at the eastern limb when it is setting.[29] People are observing the Moon from the Earth surface not from the center of the Earth, so, If there are two locations on the surface of the Earth with different coordinates, each observer in those two locations will see a different Moon's center point.

B. Moon Culmination

1. The Definition of Moon Culmination

In the Moon daily motion, the Moon moves around the Earth, starting to rise from the eastern horizon, reaching transit at the highest altitude, and setting in the western horizon. When the Earth turns on its axis, the celestial objects, include the Moon, also moves and reach their greatest altitude at the point they cross the observer's meridian. This is the meaning of the transit of celestial objects.[30]

It has to be understood that the transit or is not only defined as the position of a celestial body when it reaches the zenith, where the zenith is the highest point in celestial, which is directly above the observer's head. That is because not every day the position of celestial objects will always

[29] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia*, 227.
[30] *Ibid*, 410-411

touch the zenith point. Only those with a declination equal to the latitude of the place are sure to touch the zenith point during transit.[31]

Transit is also called culmination. The culmination happens when the celestial object reaches the observer's meridian. There are two types of culmination, the upper culmination and the lower culmination.[32] The upper culmination is defined as the culmination itself. It means that every time the celestial object reaches the meridian of the observer, that can be called the upper culmination or upper transit. If the celestial object is circumpolar[33], it may be observed to cross the meridian again 12 hours later and creates the lower culmination. For non-circumpolar object, the lower culmination cannot be observed as the object is below the horizon.

The Sun's culmination always happens at the noon. It is related to the sidereal day or the Earth's rotation period with respect to the Sun (23 hours 56 minutes 4.091 seconds).[34] The solar day or mean time interval between two successive Sun's upper transits is about four minutes longer than the sidereal day. The Sun's apparent daily motion of one degree along the ecliptic circle makes the Sun lag a little behind the equinox point so that the apparent rotation of the heavens must continue about four minutes

[31] Muhammad Hadi Bashori, *Pengantar Ilmu Falak,* 74.

[32] Sir Patrick Moore (ed), *Phillip's Atlas of Universe,* 271.

[33] Circumpolar object is a celestial object never sets below the horizon as seen by an observer due to its declination that is greater than 90° minus the latitude of the observer's location. At the Earth's equator, there are no circumpolar objects but at the Earth's poles all objects are circumpolar. See Jacqueline Mitton, *Cambridge Illustrated Dictionary of Astronomy,* (New York: Cambridge University Press), 2007, 63.

[34] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,* 366.

after each complete axial rotation of the earth, to enable the Sun to reach the meridian again.[35]

Unlike the Sun, the Moon's culmination time is uncertain as it always changes every day. It has explained before that the Moon's daily motion occurs about 51 minutes later (on the average) each day.[36] This is why the Moon culmination can occur at any time, during the day or at night. on one occasion the Moon transit can occur at zero a few minutes (standard time), then the next day it occurs at one o'clock a few minutes and so on until it returns to zero a few minutes. There is even one chance that the Moon does not transit overnight, it happens on a Moon age around the Full Moon phase.

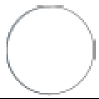
Day	Sun			Moon		
	Eqn.of Time		Mer.	Mer.Pass.		Age
	00^h mm:ss	12^h mm:ss	Pass hh:mm	Upper hh:mm	Lower hh:mm	12-14 97-100%
31	00:19	00:10	12:00	23:11	10:47	
1	00:00	00:09	12:00	23:57	11:35	
2	00:19	00:29	12:00	–:–	12:19	

Table 3.2 Transit data of the Moon and the Sun in Greenwich (source: The Nautical Almanac 2020)

Table 3.2 shows the transit data of the Moon and the Sun in Greenwich at 31 August – 2 September 2020. This table is taken from the Nautical Almanac 2020 which can be easily downloaded from the internet. In this data, the term meridian passage is used to describe transit or culmination data. As shown on the data, the Sun's transit occurs constantly at 12 GMT every day. In contrast, The Moon's transit always changes

[35] Harold Jacoby, *Astronomy: A Popular Handbook*, (New York: Mac Millan), 1913, 176.
[36] George L. Hosmer, *Textbook on Practical Astronomy*, first edition, 143.

every day. on September 31 when the Moon's age is 12 days from conjunction, the Moon's upper transit occurs at 23.11 GMT. After a day, the Moon does its transit again but in different time, 23.57 GMT. 47 minutes different from the previous day. On the next day, the Moon's culmination doesn't occur due to the transit periods must continue about fifty minutes after the previous complete culmination and the transit will happen again on the 3 October at around 00-01 GMT.

2. Calculating the Moon's Culmination Time

Although the daily Moon's culmination is uncertain, it actually can be calculated by using several formulas. This paper will explain two simple formulas to determine the time of Moon's culmination. There are by using the nautical almanac and manual calculation by using ephemeris data.

a. The Nautical Almanac

The nautical almanac has already provided the culmination data (see table 3.2). the data is based on GMT/UT of the event at 0° (Greenwich). To determine the GMT/UT time at any longitude, it has to be added or subtracted the time difference between the AP longitude and Greenwich.

$$LMT_{observer} = GMT \pm Longitude\ correction$$

Before calculating the longitude correction, find the difference between the times of the given day meridian passage and the next meridian passage if in west longitude, and the meridian passage for the preceding day if in east longitude.[37]

Then, the longitude correction can be found by doing this calculation. Let the L be the longitude of the observer and D be the difference between the tabulated times of the Moon's culmination.

$$Longitude\ correction = \frac{L}{360} \times D$$

After finding the LMT observer, apply the longitude in time to obtain the UT or the Universal time of meridian passage of the moon. Then transform the UT to the Local Civil Time (LCT) of the observer by adding the time zone.

For the example, an observer is trying to find the time of meridian passage when the Moon is passing over the longitude 110°49'35" E on 1 September, 2020.

$GMT_{mer.pass.}$	1^d	$23^h\ 57^m$	
$GMT_{mer.pass.}$	31^d	$23^h\ 11^m$	(Proceeding day)
difference		46^m	
$GMT_{mer.pass.}$	1^d	$23^h\ 57^m$	
Longitude correction		$-14^m\ 9.67^s$	(110°49'35" x 46^m / 360°)
$LMT_{mer.pass.}$ observer		$23^h\ 42^m\ 50{,}33^s$	
Longitude in time		$-7^h\ 23^m\ 18{,}33^s$	(110°49'35" / 15)
UT		$16^h\ 19^m\ 32^s$	
Zone (+7)		$+7^h$	
LCT		$23^h\ 19^m\ 32^s$	

[37] Frank Cole Stebbing, *Navigation and Nautical Astronomy*, (New York: Macmillan and Co.), 1903, 131.

b. Manual calculation by using ephemeris data

To calculate the time of the Moon's culmination, the ephemeris data should be prepared is the Sun Apparent Right Ascension (α_o), Apparent Right Ascension Moon ($\alpha_($) and Equation of Time (EoT). The complete algorithm is as follows:

1) Interpolating the Sun's apparent right Ascension (α_o)

$$\alpha_o = \alpha_o 1 - (\alpha_o 1 - \alpha_o 2) \; x \; C \; / \; I$$

2) Interpolating the Moon's apparent right Ascension ($\alpha_($)

$$\alpha_(= \alpha_(1 - (\alpha_(1 - \alpha_(2) \; x \; C \; / \; I$$

3) Finding the Sun's hour angle (t_o)

$$t_o = \alpha_(- \alpha_o$$

4) Interpolating the equation of time (EoT)

$$EoT = EoT1 - (EoT1 - EoT2) \; x \; C \; / \; I$$

5) Local Civil Time (LCT) correction

$$LCT_{cor.} = (\lambda_{std} - \lambda_{loc}) \; / \; 15$$

6) Finding the Local Civil Time

$$LCT = 12 - EoT + t_o \; / \; 15 + LCT_{cor.}$$

λ_{std} is longitude for the standard meridian of the observer from their local time zone and λ_{loc} is the local longitude of the observer. The ephemeris data are using the reference time at 12 LCT, then after the final result is known, iteration or repetition of the calculation is necessary with reference to the time of the previous calculation.

For example, an observer is trying to find the time of meridian passage when the Moon is passing over the longitude 110°49’35” E on 1 September, 2020 by using the manual method.

the ephemeris data shows that the Sun Apparent Right Ascension (α_o) at 12 LCT (5 GMT) is 160° 48' 19", Apparent Right Ascension Moon ($\alpha_($) is 331° 22' 41", and Equation of Time (EoT) on that day is 0 m 02 s.[38]

1) Finding the mer.pass. 12 LCT (5GMT)

$$LCT = 12 - EoT + t_o / 15 + LCT_{cor.}$$
$$LCT = 12 - 0^m\, 02^s + \frac{331°\, 22'41\text{-}160°\, 48'\, 19}{15} + \left(\frac{105° - 160°\, 48'\, 19"}{15}\right)$$
$$LCT = 22^h 58^m 57{,}13^s$$

2) Finding the mer.pass. $22^h\ 58^m 57{,}13^s$ LCT (iteration)

$$\alpha_o = \alpha_o 15^{GMT} - (\alpha_o 15^{GMT} - \alpha_o 16^{GMT}) \times C / I$$
$$\alpha_o = 161°\, 10'\, 57" - (161°\, 10'\, 57" - 161°\, 13'\, 12") \times 58'57{,}13" / 1$$
$$\alpha_o = 161°\, 13'9{,}64"$$

$$\alpha_(= \alpha_(15^{GMT} - (\alpha_(15^{GMT} - \alpha_(16^{GMT}) \times C / I$$
$$\alpha_(= 336°\, 27'\, 35" - (336°\, 27'\, 35" - 336°\, 57'\, 42") \times 58'57{,}13" / 1$$
$$\alpha_(= 336°\, 57'10{,}3"$$

$$EoT = EoT15^{GMT} - (EoT15^{GMT} - EoT16^{GMT}) \times C / I$$
$$EoT = 0'\, 10" - (0'\, 10" - 0'\, 11") \times 58'57{,}13" / 1$$
$$EoT = 0'\, 11"$$

$$LCT = 12 - EoT + t_o / 15 + LCT_{cor.}$$
$$LCT = 23^h 20^m 35{,}31^s$$

[38] Direktorat Urusan Agama Islam dan Pembinaan Syariah, Direktorat Jenderal Bimbingan Masyarakat Islam Kementerian Agama RI, *Ephemeris Hisab Rukyat*, 275.

The result of the Moon's calculation by using the nautical almanac and the ephemeris has a small difference, it is around 1 minute. The difference is caused by the source of nautical almanac calculation which only uses longitude correction. Then, the next discussion in this paper will use the ephemeris data as the Moon's calculation system to get higher accuracy.

C. Determining True North by Using Moon's Culmination

After finding the time of the Moon's culmination, the determination of the true north by using the Moon's culmination can be examined. But before the observation, several instruments and preparations must be completed.

1. Observation Instruments

a. Gnomon and flat plane

The main instrument of this observation is the gnomon. It has explained before that gnomon is a stick that is plugged perpendicular to a flat plane and placed in a place that is not blocked by anything to produce shadows from the Sun.[39] so, the actual function of gnomon is to cast the shadow by the Sun.

The ancient people have known that a stick set in the ground could cast a shadow, this shadow would have apparently 'infinite' length at sunrise. It would become shorter during the morning, and

[39] Susiknan Azhari, *Ensiklopedi Hisab Rukyat*, 80.

be at its shortest when the Sun was highest in the sky. This stick has helped the ancient determining the daily times, the direction, the dates of the seasons, and finding the local latitude. Later, gnomon becomes the most ancient astronomical instruments.[40]

Since the Moon is bright enough to make objects on Earth cast shadows, it might be possible to use gnomon as night astronomical instruments just as it used during the day. One of which is determining true north when the Moon is transiting. However, this observation is probably not every day can be conducted because the phases of the moon are different every day.

When using a gnomon as an astronomical instrument, it has to be prepared also a flat plane to hold the gnomon. the gnomon is set as the center of the plane, then several circles are drawn around the gnomon to mark the shadow cast by the gnomon.[41]

b. Spirit level

Spirit level, bubble level or simply a level, is a small and transparent container (usually glass) with the upper part of its inner surface curved. Spirit level is filled with a fluid of alcohol or ether, with enough free space so that an air or gas bubble always rises to the top of the container.[42] In Indonesia, spirit level is commonly

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[40] Denis Savoei, *Sundial: Design, Construction, and Use,* (Germany: Praxis Publishing Ltd.), 2009, 47.

[41] Arnold Lupton, *A Practical Treastise on Mine Surveying*, 356-357.

[42] C.V. Chelapati (ed), *Engineering Surveying P.E. (Civil) License Review Manual*, (Long Beach, CA: Professional Engineering Development Publications), 1994, B-35.

known as waterpass. There are two types of spirit levels, the one is spherically curved surface spirit level. This level has a bubble appear circular when viewed from above. The other one is a level shaped like a curved cylinder. This is the commonly used level in surveying or astronomical instruments for precisely referring the horizontal plane or to the zenith.

Figure 3.5 Spherical spirit level (left) and cylinder spirit level (right) (source: Google)

In astronomical practice, spirit level is used to measure the deviations of line or surface from a vertical or horizontal position, and adjust a part of an instrument to such a position.[43] In the Moon culmination's observation, the spirit level is used to adjust the flat plane before setting up the gnomon.

c. Accurate timepiece

The timepiece is used to record the Moon culmination's time during field observation. To see the accurate time can be obtain by several ways:[44]

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[43] George C. Comstock, *A Text-Book of Field Astronomy for Engineers,* (New York: J. Wiley & Sons), 1902, 99-100.

[44] Slamet Hambali, *Seminar Nasional Uji Kelayakan Istiwaain Sebagai Alat Bantu Menentukan Arah Kiblat yang Akurat,* (Semarang: Prodi Ilmu Falak IAIN Walisongo), 2013, 9.

1) Adjusts to the clock in the Global Positioning System (GPS) that is currently connected to the satellite.

2) Adjust the online time available on the website. Such as: http://jam.bmkg.go.id/Jam.BMKG, and https://time.is/id/.

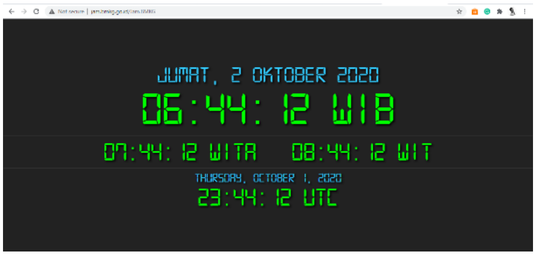

Figure 3.6 the appearance of jam.bmkg.go.id

d. Other supporting instruments

Other instruments are needed to support this observation, such as a ruler and marker to mark the line of the true north, a ruler arc to bring the true north line to the Qibla azimuth, a book to record the Moon's culmination time and the result of the observation, and camera to capture the documentation during the observation.

2. Observation Procedure

Field observations to determine true north using the Moon's culmination should be conducted at night in a relatively dark place. This means that there is no light that has the potential to interfere with the Moon's rays in order to minimize errors in observing the shadow by the Moon's light when the Moon actually reaches the meridian (true north-south line).

The steps for determining true north can be practiced using the Sun or the Moon, as follows:[45]

1) Find a location that has open and level ground. Check the level of the ground using a spirit level.
2) By using the flat plane, draw circles around the center point of the plane. The smaller the circle, the shorter the time span, which will make the result more accurate.
3) Set a gnomon on the plane, the longer and smaller the stick, the shorter the time span, so that the results of the observation are more accurate.
4) A few minutes before culmination, mark the point at the end of the shadow cast by the pole then making a mark after the culmination with radius equal to the previous mark.[46]
5) the true east-west line can be created after finding the intersection point of the Moon's shadow with the circle before and after culmination.
6) The true north direction can be obtained by cutting the east and west lines 90^{o} with a ruler arc.

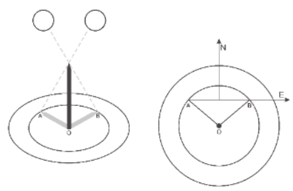

Figure 3.7 determining the true north using Moon’s culmination

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[45] Ahmad Izzuddin, *Menentukan Arah Kiblat Praktis*, 50

[46] Arnold Lupton, *A Practical Treastise on Mine Surveying,* 356-357.

CHAPTER IV

THE ANALYSIS OF THE ACCURACY OF USING MOON'S CULMINATION IN DETERMINING TRUE NORTH AND THE APPLICATION IN DETERMINING QIBLA DIRECTION

A. The Analysis of Method of Using the Moon's Culmination in Determining True North

The basis for determining true north using the culmination of the Moon is not much different from the basis for determining true north using the Sun's culmination. Even if it is seen from the practice procedure there is no difference at all. The data taken from field observations are also the same, it is the time when the culmination happens.

The basic difference from determining the true north with the Moon's culmination and with the Sun's culmination is the obstacle when doing the observation. when using the Sun as a reference for observation, the obvious obstacle is the weather. If the Sun is blocked by a thick cloud when it is culminating, the gnomon will not cast a shadow. When using the Moon to determine true north, the obstacles that happen during the observation are not only the weather but there are still things that cause the observations cannot be conducted or even fail. There are at least two more obstacles, the limited research time and the light pollution at the observation location.

The use of the Moon's culmination for determining true north cannot be practiced every day. The observation can only be conducted when the Moon culminates at night. It is the time when the Moon’s culmination can clearly be seen by naked eyes. It has also been discussed that the Moon’s culmination happens in uncertainty. It can happen at any time of the day. That is because the Moon’s daily motion occurs about 51 minutes later (on the average) each day.

Date	Day	Moon Mer.Pass.	Moon Age	Date	Day	Moon Mer.Pass.	Moon Age
1	Tuesday	23:20:35	13	17	Thursday	11:24:49	29
2	Wednesday	--------	14	18	Friday	12:18:07	30
3	Thursday	00:04:26	15	19	Saturday	13:11:09	1
4	Friday	00:46:39	16	20	Sunday	14:04:42	2
5	Saturday	01:27:36	17	21	Monday	14:59:27	3
6	Sunday	02:08:09	18	22	Tuesday	15:55:35	4
7	Monday	02:49:09	19	23	Wednesday	16:52:47	5
8	Tuesday	03:31:30	20	24	Thursday	17:50:04	6
9	Wednesday	04:15:57	21	25	Friday	18:46:10	7
10	Thursday	05:03:09	22	26	Saturday	19:39:53	8
11	Friday	05:53:26	23	27	Sunday	20:30:31	9
12	Saturday	06:46:40	24	28	Monday	21:17:58	10
13	Sunday	07:42:09	25	29	Tuesday	22:02:34	11
14	Monday	08:38:41	26	30	Wednesday	22:45:00	12
15	Tuesday	09:35:07	27				
16	Wednesday	10:30:36	28				

Table 4.1. the Moon’s culmination data on September 2020[1]

Not only when the time of the Moon can be seen with the naked eye, but the phase of the Moon also affects the observation time. As seen in the table 4.1., this table provides the Moon’s culmination data on September 2020 in Surakarta, Indonesia (lat. 7°32’26” S, long. 110°49’35” E). We assume the night has a time range from 18.00 to 5.00, it is when the Sun’s light possibly

[1] As explained in chapter III, there are two different ways in calculating the Moon’s culmination time. The first is using the Moon’s meridian passage data provided in the Nautical Almanac which is the calculation is only needed the transformation from Greenwich time to local time. The second is by calculating manually using the ephemeris data. The writer prefers to use the manual calculation due to the purpose of the calculation is to predict the exact time of the Moon’s culmination.

has not affected the night sky. So, in this data, the Moon's culmination which occurs at night can be seen at the Moon age of 7-21. In fact, as is well known, every day the Moonlight does not have the same intensity due to the different phases of the Moon.

The Moon should have enough light so that objects on Earth can cast shadows and this is not possible when the Moon is in the crescent phase. Based on the data in table 4.1, At September 2, there is no Moon culmination occurs. It happens because the time the Moon to culminate again after previous culmination is incomplete, then the next culmination occurs at September 3, 00.04 LCT. The Moon age indicates the phase that the Moon is currently in. At 10-24 September the Moon's culmination is cannot be observe because the Moon is in crescent and new Moon phase, also the data shows that at these dates the culmination time occurs when the Sunlight still affected the sky. The first quarter of the Moon happens at September 25 (Moon age 7) and the third quarter phase happens at September 9 (Moon age 21). In these both Moon phases, the light of the Moon is very dim then the gnomon is still difficult to cast the Moon shadow. Based on writer's observation, the gnomon can start to cast clear shadows when the Moon enters the gibbous phase and it is getting clearer when enters the full moon phase.[2]

[2] The writer conducted observations of Moonlight in a place with low lighting. The shadow casted by the gnomon is unclear and very vague when the Moon in the first quarter phase.

Therefore, it can be concluded that the observation of the Moon's culmination in determining the true north can be conducted at the Moon age 10 until 20 or when the Moon starts to enter the gibbous phase. Meanwhile, the best time is when the Moon is in the full Moon phase and a day before and after full Moon..

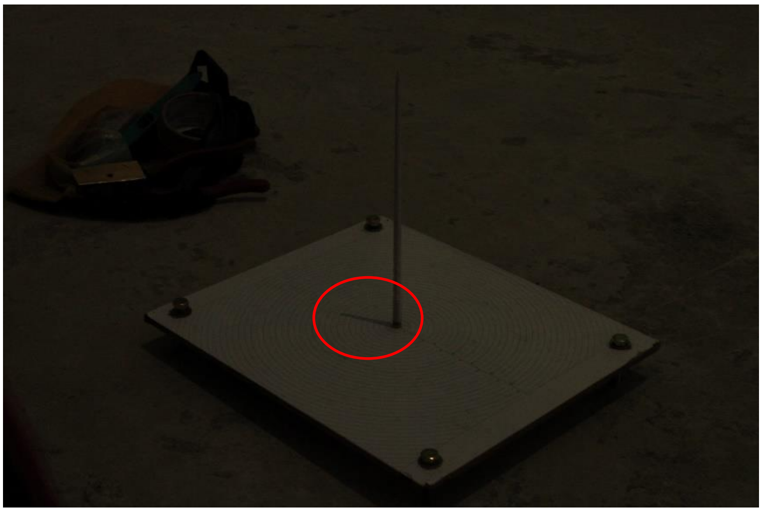

Figure 4.1. Moon shadow casted by a gnomon at 31 August (Moon age 12 or gibbous phase)

It is possible to observe the Moon at several days in each month. The unique fact that the gibbous phase, from the wanning gibbous, full moon, and waxing gibbous constantly happens at night. But it has to be considered that the observation should be conducted in the place with low light or less light pollution because the observation relies on the moonlight. if the light around the observation location is brighter than the moonlight, it will interfere with the gnomon to cast the Moon shadow.

When the Moon reaches its highest altitude when it is culminating, the shadow will point to the north or south. The length of the shadow will vary depending on the observation time. The variant of the shadow length is caused by the declination of the Moon.[3] The Moon's orbit is inclined at angle about 5°08' to the plane of the Earth's orbit. When these two planes' line of intersection rotates in a similar manner in every 18,6 years (approximately), the phases of the Moon will recur on the same day of the year. This is called the Metonic cycle. Therefore, the Moon's maximum declination varies form 28° 35' (23°27'+5°08') to 18° 19' (23°27'-5°08') according to the relative position of the plane of the moon's orbit and the plane of the equator.[4]

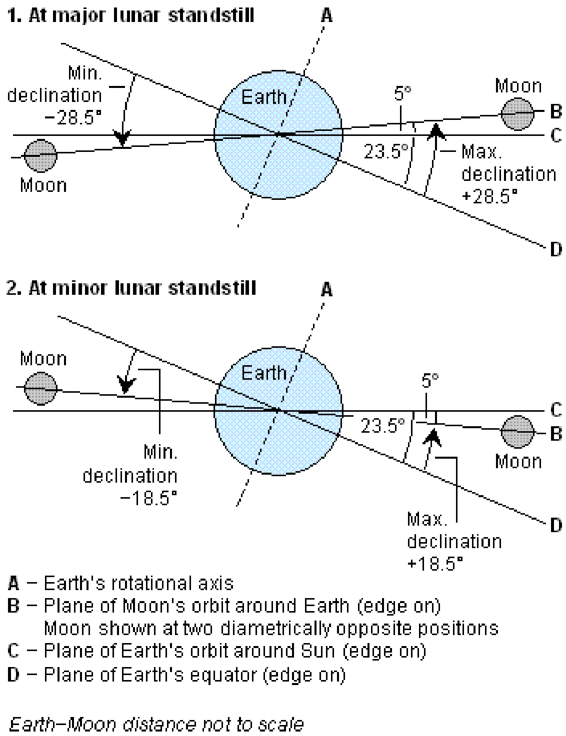

Figure 4.2. major and minor lunar standstill

The Moon's declination range is gradually varying between the northern limits and the southern limits and this is called the lunar standstill. in every 18,6

[3] Declination is a celestial coordinate measured as the angle from the celestial equator. See Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedia,*111.

[4] George L. Hosmer, *Textbook on Practical Astronomy*, 141-142.

years one major or one minor lunar standstill occurs due to the metonic cycle. As seen in figure 4.2, a major lunar standstill occurs when the Moon's declination reaches a maximum monthly limit, stopping at 28° 35' north or south and a minor lunar standstill occurs when the Moon's declination reaches a minimum monthly limit, stopping at 18° 19' north or south.

When the Moon's declination becomes equal to the latitude of the place, the Moon does not cast a shadow of an object because it is exactly at zenith. It can be said that the Moon is still cast the shadow but it is exactly under the object and not point to any south or north direction. When it is happening, the Moon's culmination observation to determine true north cannot be conducted. It is not possible also doing an observation when the declination of the Moon is almost close to the latitude of the place. The shadow casted by the Moon will be very short and could not measure accurately.

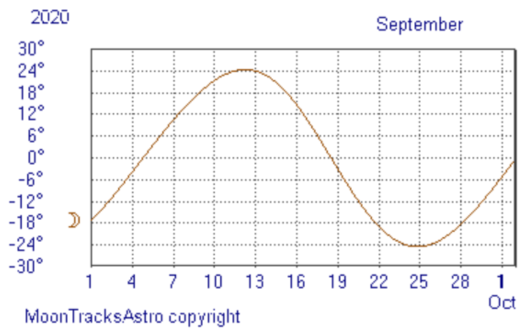

Figure 4.2. Moon declination on September 2020

Therefore, before the observation, the declination value must be known at the time the Moon's culmination occurs. he higher the declination value, the longer the moon shadow casted by the gnomon, then the observation can be easily conducted.

B. The Analysis of the Accuracy of Using the Moon's Culmination in Determining True North and Its Application in Determining the Qibla Direction

The first step in determining true north using the Moon's culmination is finding the location with low light or less light pollution that can disturb the moonlight. The writer chose to do research at the Astronomy Laboratory *(Laboratorium Falak)*, MAPK MAN 1 Surakarta. This laboratory is located in Surakarta City, which actually has quite high light pollution. However, the laboratory building is located on the 5th floor and is the tallest building in surroundings so the light from other buildings cannot reach the laboratory building.

Figure 4.3. Astronomy Laboratory, MAPK MAN 1 Surakarta

The writer then looks for the data of the observation location, such as the altitude, latitude, and longitude. This data is used in calculating the Moon's culmination time. The data can be found by using GPS[5] or google maps. In this observation, the writer used the GPS then found the data below:

[5] The writer used the GPS test, an android application that has a function similar to GPS.

Astronomy Laboratory, MAPK MAN 1 Surakarta	
Longitude	110°49’35” E
Latitude	7°32’26” S
Altitude (m)	139

Table 4.2 Location data of Astronomy laboratory, MAPK MAN 1 Sukarakarta

After finding the location data, the writer calculated the Moon’s culmination time to determine the observation time. In calculating the culmination time, the writer was using the manual calculation and taking the data such as the Moon and Sun’s apparent right accession, equation of time, and declination in Ephemeris.

Date	Day	Moon Mer.Pass.	Moon Age	Date	Day	Moon Mer.Pass.	Moon Age
1	Tuesday	23:20:35	13	17	Thursday	11:24:49	29
2	Wednesday	--------	14	18	Friday	12:18:07	30
3	Thursday	00:04:26	15	19	Saturday	13:11:09	1
4	Friday	00:46:39	16	20	Sunday	14:04:42	2
5	Saturday	01:27:36	17	21	Monday	14:59:27	3
6	Sunday	02:08:09	18	22	Tuesday	15:55:35	4
7	Monday	02:49:09	19	23	Wednesday	16:52:47	5
8	Tuesday	03:31:30	20	24	Thursday	17:50:04	6
9	Wednesday	04:15:57	21	25	Friday	18:46:10	7
10	Thursday	05:03:09	22	26	Saturday	19:39:53	8
11	Friday	05:53:26	23	27	Sunday	20:30:31	9
12	Saturday	06:46:40	24	28	Monday	21:17:58	10
13	Sunday	07:42:09	25	29	Tuesday	22:02:34	11
14	Monday	08:38:41	26	30	Wednesday	22:45:00	12
15	Tuesday	09:35:07	27				
16	Wednesday	10:30:36	28				

Table 4.3. the Moon’s culmination data at Astronomy Laboratory, September 2020

The writer planned to observe the Moon at the first week of September. The table 4.3 shows the culmination times on September 2020. As discussed before, the time to observe the Moon’s culmination is when the Moon is in the gibbous phase. So, on September the observation can be conducted at September 1 until September 20 then continue from September 28 until 30. But due to the permission issue and the climate, the observation can only be conducted in 4 days, from August 31, September 1, and September 3 to 4.

The gnomon used in the observation has 22cm of length. When the Moon's culmination was occurring, the writer recorded the length of the Moon's shadow and got the result below. The declination of the Moon varied each day when the observation was conducted so that the gnomon cast varying Moon's shadow.[6] The shortest shadow was recorded at the August 31 observation.

Date	Moon Mer. Pass.	Declination	Shadow Length (cm)	Shadow direction
August 31	22:33:06	5°15'44"	4,9	South
September 1	23:20:25	9°53'24"	6,9	South
September 3	00:04:26	14°09'43"	8,7	South
September 4	00:46:39	17°54'46"	10,5	South

Table 4.4 Moon's shadow length casted by gnomon

The observation is by marking the point at the end of the shadow cast by the pole a view minutes before the culmination then marking after the culmination with a radius equal to the previous mark. The writer set the time marking point range 10 minutes before and after the culmination for each observation. By connecting those 2 marking points, the true east-west direction can be created.

After finding the east-west direction, the true north can be obtained by cutting the east and west lines 90° with a ruler arc. Based the observation that was conducted by the writer, the result can be shown below.

[6] The declination data was taken from the Ephemeris and has been interpolated with the exact culmination time.

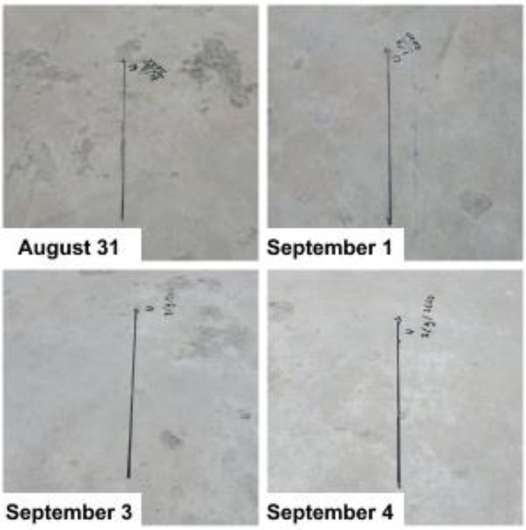

Figure 4.4 Observation result in determaing true north

The result of the four observations shown an almost similar north direction. However, there were slight deviations. To determine these deviations and test the accuracy of the results, the authors compared the results of the true north determination using Moon's culmination with the determination of true north using Sun's culmination.

The Sun's culmination observation method is the same as the Moon's culmination method, the main required data is the Sun's culmination time at the day. The Sun's culmination always happens at the noon, unlike the Moon's culmination time that always changes every day. Then, to determine the culmination time of the Sun is practically simpler. Since the Sun's culmination always happens at 12 AST than the required data to calculate it are the longitude and latitude of the place and equation of time at 12 LCT. The formula to calculate the Sun's culmination at local time is written below.

$$Local\ Sun\ Mer.Pass = 12 - EoT + (\lambda_{std} - \lambda_{loc}) / 15$$

λ_{std} is longitude for the standard meridian of the observer from their local time zone, λ_{loc} is the local longitude of the observer, and *EoT* is the equation of time at 12.00 local time, this data can be found in the ephemeris.

The writer observed the Sun's culmination at September 17, 2020 with the equation of time 5'33". So, the data at the culmination of the Sun can be obtained below.

Longitude	110°49'35" E
Latitude	7°32'26" S
Equation of time	5'33"
Moon Mer. Pass.	11:31:08
Declination	2°5'15"
Gnomon height	22
Gnomon length	6,8
Shadow direction	South

Table 4.5 Sun's culmination data

The result of the Sun's culmination in determining true north when compared with the results of determining true north with the Moon, it looks like this:

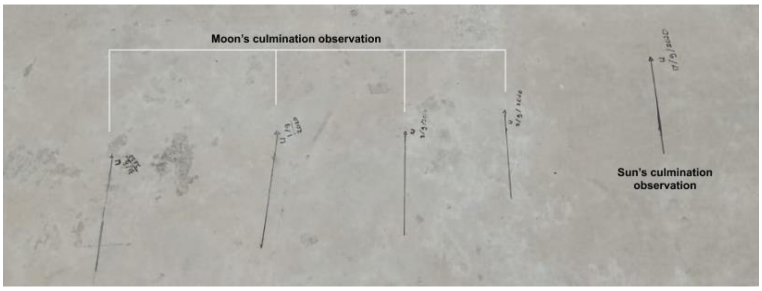

Figure 4.5 True North from Moon and Sun's culmination observation

As seen in the figure 4.5, the results in determining true north using Moon's culmination and Sun's culmination have slight deviations. The September 3 observation result (three from left) has the same direction with the Sun's culmination observation result. At that time, the Moon was at the age of

15 or in full moon phase. And the largest deviation was found in the September 1 observation result.

By using an arc ruler, it can be seen the value of the deviation in the result of each day (see the table 4.6). The August 31 observation has 1° deviation to the true north by using the Sun’s culmination. It is a small deviation. But suddenly, the result on September 1 shows a big deviation as it is 4,5° different. The reason is when the observation was conducted, the weather of that time was cloudy and rarely the gnomon could clearly cast the shadow. Then the September 1 observation shows an amazing result as it has no deviation or zero different with the Sun’s culmination method. Then the September 4, it still has a little deviation, 0,5°.

Date	**Deviation**
August 31	1°
September 1	4,5°
September 3	0°
September 4	0,5°

Table 4.6 Deviation data

These results prove that the Moon's culmination method for determining true north has a result that is close to the Sun's culmination method, which is a common method for determining true north. However, this method has not been tested for accuracy with modern tools such as theodolite, due to the unavailability of tools. There is a possibility of a larger deviation when tested for accuracy with theodolite or other modern tools. But these results are sufficient to test the feasibility of the culmination of the Moon to determine true north, because many tools still use the shadows of celestial bodies (Sun) such as *istiwa 'aini* and *mizwala*.

As explained in Chapter II, the true north is needed in determining the azimuth of the Qibla. Azimuth is defined as Angular distance of an object measured westwards around the horizon from due north at 0º, through due east at 90º, due south at 180º and so on.[7] true north is the 0º point from which the azimuth measurement starts. To find the qibla azimuth, a formula like this is used.

$$Q = \tan^{-1} \frac{\sin(\lambda_{loc} - \lambda_m)}{[(\cos \phi_{loc}) \times (\tan \phi_m)] - [(\sin \phi_{loc}) \times (\cos \lambda_{loc} - \lambda_m)]}$$

The required data in determining the Qibla azimuth are λ_{loc} (longitude of desired location), ϕ_{loc} (latitude of desired location), λ_m (longitude of Mecca), and ϕ_m (latitude of Mecca). The coordinate of the location can be found in figure 4.2. then the writer uses the coordinate of Mecca that written in a book by Ahmad Izzuddin, "Ilmu Falak Praktis".[8] The longitude of Mecca is 39°49'34,56" E and the latitude of Mecca is 21°25'21,17" N.

The writer will not explain the calculation process, but the result can be seen below.

Longitude of desired location	110°49'35" E
Latitude of desired location	7°32'26" S
Longitude of Mecca	39°49'34,56" E
Latitude of Mecca	21°25'21,17" N
Qibla Azimuth	294°32'23,4"
Qibla direction	West from True North

Table 4.7 Qibla azimuth data

[7] Sir Patrick Moore (ed), *Phillip's Astronomy Encyclopedy,* 44.
[8] Ahmad Izzuddin, *Ilmu Falak Praktis,* 30.

By using the true north direction from September 3 observation, the Qibla direction can be measured with an arc ruler. To make the measurement easier, subtract the degrees of a full circle from the Qibla azimuth, 360° - 294°32’23,4” = 65°27’36,6”. It will be found the west to north direction. The method is illustrated below.

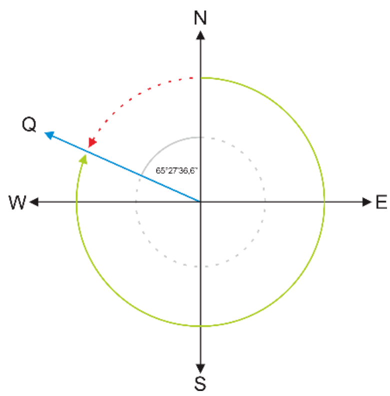

Figure 4.6 The Qibla azimuth

The observation result shows that the true north determination using the Moon’s culmination has no difference from the Sun’s culmination observation. Then the result in determining the Qibla direction also has the same result. However, there is a small deviation in some observations but the deviation is not too far from the Sun’s culmination observation. The deviation might be caused by the error when marking the before-after culmination point or caused by a cloud covering the Moon so the shadow becomes blurred. The writer recommends to conduct more than one observation when using the Moon’s culmination to determine the true north and apply it to the Qibla direction.

See all the explanations above starting from the method of determining true north using the Moon’s culmination, the practice and the application in the

Qibla direction, this method can be used as a new alternative which this method has never existed before. Based on the results of the research, the writer concluded that the Moon's culmination method can be used as a reference for determining the true north and applied to determine the Qibla direction or for other observation related to ‘*Ilm Falak* or Astronomy discussion.

In the end of this discussion, the writer gives his view and interpretation of the method using the Moon as the object of the observation, based on the writer’s experience in field observation. The Moon can be an alternative method and object in ‘*Ilm Falak* or Astronomy discussion. However, the obstacles that happen during the Moon observation are not only the weather but there are still things that cause the observations cannot be conducted or even fail. There are at least two more obstacles, the limited research time and the light pollution at the observation location.

The large number of obstacles led to the lack of observations of the Moon. Whereas based on the author's research, the results of the observations are not bad and are even closer to the results of the existing research method. With the proper method and tools, the Moon observation can obtain accurate result. So, the writer hopes that there will be more observations and researches using the Moon as the object. It will enrich the discussion of ‘*Ilm Falak* or Astronomy.

CHAPTER V

CLOSING

A. Conclusion

The research of culmination of the moon as true north determinant and its application in qibla direction has conclusions as below:

1. The method in determining true north using the Moon's culmination is the same as the method using the Sun's culmination. The difference is that the Moon's culmination method uses the Moon when it is transiting in the meridian as the main reference. There are two formulas in determining the Moon's culmination time. the first is by transforming the Moon upper meridian pass data provided in the Nautical Almanac to the local time. the second is by manual calculation using the ephemeris data. The required data to calculate the Moon's culmination time are the coordinate of desired place, Sun Apparent Right Ascension (α_{o}), Apparent Right Ascension Moon ($\alpha_{(}$) and Equation of Time (*EoT*). To get the more precise data, it is recommended to calculate the Moon's culmination time using the manual calculation. The calculation and the observation show that the observation of Moon's culmination to determine true north can be conducted at the Moon age 10 until 20 or when the Moon stars to enter the gibbous phase. Meanwhile, the best time is when the Moon is in the full Moon phase and a day before and after full Moon.

2. The result of determining true north using the Moon’s culmination shows that this method has almost similar result with the method of the Sun’s culmination. It has slight deviation. The deviation might be caused by the error when marking the before-after culmination point or caused by a cloud covering the Moon so the shadow becomes blurred. It is recommended to conduct more than one observation when using the Moon’s culmination to determine the true north and apply it to the Qibla direction. the writer concluded that the Moon's culmination method can be used as a reference for determining the true north and applied to determine the Qibla direction or for other observation related to *‘Ilm Falak* or Astronomy discussion.

B. Suggestion

After doing the research, the writer has some suggestion:

1. For universities and academics to be able to socialize this new method using the Moon’s culmination as an alternative for determining true north.
2. The Moon has many aspects that can be discussed in the research. This research can be used as material for other research, related to the Moon’s culmination in more varied areas.

C. Closing

Thanks to God, Allah SWT who has bestowed us, health, favor, iman, and Islam. Peace be upon our Prophet Muhammad SAW whose intercession we always hope on the day of judgment.

On this last section, the writer realizes that in writing this thesis there are still many mistakes. The writer will be delighted to accept criticism, suggestions to make this thesis is better in any perspective. Finally, the writer hopes this research gives advantages for future learning, research, and other purposes.

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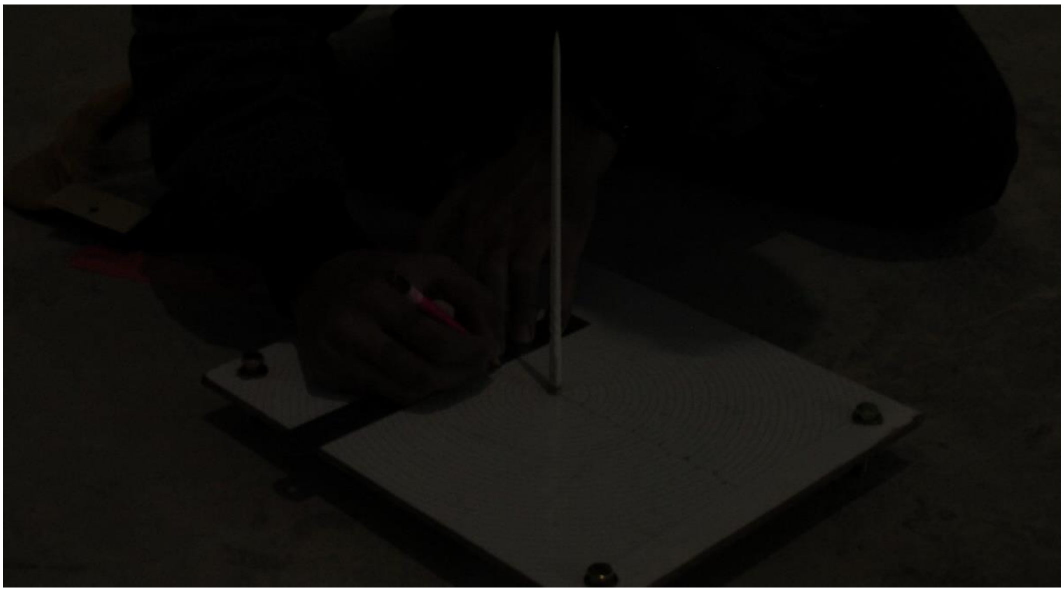
ATTACHMENT

Moon’s Culmination Observation in Determining True North at Astronomy Laboratory, MAPK MAN 1 Surakarta



Sun's Culmination Observation in Determining True North at Astronomy Laboratory, MAPK MAN 1 Surakarta

Ephemeris Data (August 31, September 1, and September 3-4)

31 Agustus 2020

DATA MATAHARI

Jam	Ecliptic Longitude *)	Ecliptic Latitude *)	Apparent Right Ascension	Apparent Declination	True Geocentric Distance	Semi Diameter	True Obliquity	Equation Of Time
0	158° 03' 47"	-0.59"	159° 42' 36"	8° 32' 56"	1.0094288	15' 50.67"	23° 26' 13"	0 m -20 s
1	158° 06' 12"	-0.60"	159° 44' 53"	8° 32' 02"	1.0094189	15' 50.68"	23° 26' 13"	0 m -20 s
2	158° 08' 37"	-0.60"	159° 47' 09"	8° 31' 08"	1.0094090	15' 50.69"	23° 26' 13"	0 m -19 s
3	158° 11' 02"	-0.61"	159° 49' 25"	8° 30' 14"	1.0093991	15' 50.69"	23° 26' 13"	0 m -18 s
4	158° 13' 27"	-0.61"	159° 51' 41"	8° 29' 19"	1.0093891	15' 50.70"	23° 26' 13"	0 m -17 s
5	158° 15' 52"	-0.62"	159° 53' 57"	8° 28' 25"	1.0093792	15' 50.71"	23° 26' 13"	0 m -17 s
6	158° 18' 17"	-0.62"	159° 56' 13"	8° 27' 31"	1.0093693	15' 50.72"	23° 26' 13"	0 m -16 s
7	158° 20' 42"	-0.62"	159° 58' 29"	8° 26' 37"	1.0093594	15' 50.73"	23° 26' 13"	0 m -15 s
8	158° 23' 07"	-0.63"	160° 00' 45"	8° 25' 43"	1.0093494	15' 50.74"	23° 26' 13"	0 m -14 s
9	158° 25' 32"	-0.63"	160° 03' 01"	8° 24' 48"	1.0093395	15' 50.75"	23° 26' 13"	0 m -13 s
10	158° 27' 57"	-0.64"	160° 05' 17"	8° 23' 54"	1.0093296	15' 50.76"	23° 26' 13"	0 m -13 s
11	158° 30' 22"	-0.64"	160° 07' 33"	8° 22' 60"	1.0093196	15' 50.77"	23° 26' 13"	0 m -12 s
12	158° 32' 47"	-0.64"	160° 09' 49"	8° 22' 06"	1.0093097	15' 50.78"	23° 26' 13"	0 m -11 s
13	158° 35' 12"	-0.65"	160° 12' 05"	8° 21' 11"	1.0092997	15' 50.79"	23° 26' 13"	0 m -10 s
14	158° 37' 37"	-0.65"	160° 14' 20"	8° 20' 17"	1.0092898	15' 50.80"	23° 26' 13"	0 m -9 s
15	158° 40' 02"	-0.65"	160° 16' 36"	8° 19' 23"	1.0092798	15' 50.81"	23° 26' 13"	0 m -9 s
16	158° 42' 28"	-0.66"	160° 18' 52"	8° 18' 28"	1.0092699	15' 50.82"	23° 26' 13"	0 m -8 s
17	158° 44' 53"	-0.66"	160° 21' 08"	8° 17' 34"	1.0092599	15' 50.83"	23° 26' 13"	0 m -7 s
18	158° 47' 18"	-0.66"	160° 23' 24"	8° 16' 40"	1.0092500	15' 50.83"	23° 26' 13"	0 m -6 s
19	158° 49' 43"	-0.67"	160° 25' 40"	8° 15' 45"	1.0092400	15' 50.84"	23° 26' 13"	0 m -6 s
20	158° 52' 08"	-0.67"	160° 27' 56"	8° 14' 51"	1.0092301	15' 50.85"	23° 26' 13"	0 m -5 s
21	158° 54' 33"	-0.68"	160° 30' 12"	8° 13' 57"	1.0092201	15' 50.86"	23° 26' 13"	0 m -4 s
22	158° 56' 58"	-0.68"	160° 32' 28"	8° 13' 02"	1.0092101	15' 50.87"	23° 26' 13"	0 m -3 s
23	158° 59' 23"	-0.68"	160° 34' 44"	8° 12' 08"	1.0092002	15' 50.88"	23° 26' 13"	0 m -2 s
24	159° 01' 48"	-0.69"	160° 36' 60"	8° 11' 13"	1.0091902	15' 50.89"	23° 26' 13"	0 m -2 s

*) for mean equinox of date

DATA BULAN

Jam	Apparent Longitude	Apparent Latitude	Apparent Right Ascension	Apparent Declination	Horizontal Parallax	Semi Diameter	Angle Bright Limb	Fraction Illumination
0	312° 25' 12"	-3° 36' 58"	315° 57' 59"	-20° 32' 33"	0° 55' 53"	15' 13.78"	245° 51' 55"	0.95012
1	312° 56' 53"	-3° 38' 53"	316° 30' 54"	-20° 25' 17"	0° 55' 52"	15' 13.46"	245° 28' 32"	0.95192
2	313° 28' 33"	-3° 40' 47"	317° 03' 45"	-20° 17' 56"	0° 55' 51"	15' 13.13"	245° 4' 46"	0.95368
3	314° 00' 12"	-3° 42' 41"	317° 36' 31"	-20° 10' 29"	0° 55' 50"	15' 12.81"	244° 40' 36"	0.95541
4	314° 31' 50"	-3° 44' 32"	318° 09' 13"	-20° 02' 56"	0° 55' 49"	15' 12.49"	244° 16' 01"	0.95711
5	315° 03' 26"	-3° 46' 23"	318° 41' 50"	-19° 55' 17"	0° 55' 47"	15' 12.16"	243° 50' 59"	0.95877
6	315° 35' 02"	-3° 48' 13"	319° 14' 23"	-19° 47' 33"	0° 55' 46"	15' 11.84"	243° 25' 27"	0.96040
7	316° 06' 36"	-3° 50' 01"	319° 46' 51"	-19° 39' 43"	0° 55' 45"	15' 11.53"	242° 59' 25"	0.96199
8	316° 38' 09"	-3° 51' 48"	320° 19' 15"	-19° 31' 47"	0° 55' 44"	15' 11.21"	242° 32' 48"	0.96355
9	317° 09' 42"	-3° 53' 33"	320° 51' 35"	-19° 23' 46"	0° 55' 43"	15' 10.89"	242° 5' 36"	0.96507
10	317° 41' 13"	-3° 55' 18"	321° 23' 50"	-19° 15' 40"	0° 55' 42"	15' 10.58"	241° 37' 45"	0.96656
11	318° 12' 43"	-3° 57' 01"	321° 56' 00"	-19° 07' 28"	0° 55' 40"	15' 10.26"	241° 9' 13"	0.96802
12	318° 44' 12"	-3° 58' 43"	322° 28' 07"	-18° 59' 11"	0° 55' 39"	15' 09.95"	240° 39' 55"	0.96944
13	319° 15' 40"	-4° 00' 23"	323° 00' 08"	-18° 50' 49"	0° 55' 38"	15' 09.64"	240° 9' 50"	0.97083
14	319° 47' 07"	-4° 02' 02"	323° 32' 06"	-18° 42' 21"	0° 55' 37"	15' 09.33"	239° 38' 52"	0.97219
15	320° 18' 33"	-4° 03' 40"	324° 03' 59"	-18° 33' 49"	0° 55' 36"	15' 09.02"	239° 6' 59"	0.97351
16	320° 49' 58"	-4° 05' 17"	324° 35' 47"	-18° 25' 11"	0° 55' 35"	15' 08.71"	238° 34' 05"	0.97479
17	321° 21' 21"	-4° 06' 52"	325° 07' 31"	-18° 16' 29"	0° 55' 34"	15' 08.40"	238° 0' 06"	0.97604
18	321° 52' 44"	-4° 08' 26"	325° 39' 11"	-18° 07' 41"	0° 55' 32"	15' 08.09"	237° 24' 55"	0.97726
19	322° 24' 06"	-4° 09' 59"	326° 10' 46"	-17° 58' 49"	0° 55' 31"	15' 07.79"	236° 48' 28"	0.97844
20	322° 55' 26"	-4° 11' 30"	326° 42' 17"	-17° 49' 52"	0° 55' 30"	15' 07.48"	236° 10' 36"	0.97959
21	323° 26' 46"	-4° 13' 01"	327° 13' 44"	-17° 40' 50"	0° 55' 29"	15' 07.18"	235° 31' 14"	0.98070
22	323° 58' 04"	-4° 14' 29"	327° 45' 06"	-17° 31' 43"	0° 55' 28"	15' 06.88"	234° 50' 13"	0.98178
23	324° 29' 21"	-4° 15' 57"	328° 16' 24"	-17° 22' 32"	0° 55' 27"	15' 06.58"	234° 7' 23"	0.98283
24	325° 00' 38"	-4° 17' 23"	328° 47' 37"	-17° 13' 17"	0° 55' 26"	15' 06.28"	233° 22' 35"	0.98384

1 September 2020

DATA MATAHARI

Jam	Ecliptic Longitude *)	Ecliptic Latitude *)	Apparent Right Ascension	Apparent Declination	True Geocentric Distance	Semi Diameter	True Obliquity	Equation Of Time
0	159° 01' 48"	-0.69"	160° 36' 60"	8° 11' 13"	1.0091902	15' 50.89"	23° 26' 13"	0 m -2 s
1	159° 04' 13"	-0.69"	160° 39' 15"	8° 10' 19"	1.0091802	15' 50.90"	23° 26' 13"	0 m -1 s
2	159° 06' 38"	-0.69"	160° 41' 31"	8° 09' 25"	1.0091702	15' 50.91"	23° 26' 13"	0 m 00 s
3	159° 09' 03"	-0.69"	160° 43' 47"	8° 08' 30"	1.0091603	15' 50.92"	23° 26' 13"	0 m 01 s
4	159° 11' 29"	-0.70"	160° 46' 03"	8° 07' 36"	1.0091503	15' 50.93"	23° 26' 13"	0 m 02 s
5	159° 13' 54"	-0.70"	160° 48' 19"	8° 06' 41"	1.0091403	15' 50.94"	23° 26' 13"	0 m 02 s
6	159° 16' 19"	-0.70"	160° 50' 35"	8° 05' 47"	1.0091303	15' 50.95"	23° 26' 13"	0 m 03 s
7	159° 18' 44"	-0.71"	160° 52' 50"	8° 04' 52"	1.0091203	15' 50.96"	23° 26' 13"	0 m 04 s
8	159° 21' 09"	-0.71"	160° 55' 06"	8° 03' 57"	1.0091103	15' 50.97"	23° 26' 13"	0 m 05 s
9	159° 23' 34"	-0.71"	160° 57' 22"	8° 03' 03"	1.0091004	15' 50.98"	23° 26' 13"	0 m 06 s
10	159° 25' 59"	-0.72"	160° 59' 38"	8° 02' 08"	1.0090904	15' 50.99"	23° 26' 13"	0 m 06 s
11	159° 28' 24"	-0.72"	161° 01' 54"	8° 01' 14"	1.0090804	15' 50.99"	23° 26' 13"	0 m 07 s
12	159° 30' 49"	-0.72"	161° 04' 09"	8° 00' 19"	1.0090704	15' 51.00"	23° 26' 13"	0 m 08 s
13	159° 33' 14"	-0.72"	161° 06' 25"	7° 59' 25"	1.0090604	15' 51.01"	23° 26' 13"	0 m 09 s
14	159° 35' 40"	-0.73"	161° 08' 41"	7° 58' 30"	1.0090504	15' 51.02"	23° 26' 13"	0 m 10 s
15	159° 38' 05"	-0.73"	161° 10' 57"	7° 57' 35"	1.0090403	15' 51.03"	23° 26' 13"	0 m 10 s
16	159° 40' 30"	-0.73"	161° 13' 12"	7° 56' 41"	1.0090303	15' 51.04"	23° 26' 13"	0 m 11 s
17	159° 42' 55"	-0.73"	161° 15' 28"	7° 55' 46"	1.0090203	15' 51.05"	23° 26' 13"	0 m 12 s
18	159° 45' 20"	-0.74"	161° 17' 44"	7° 54' 51"	1.0090103	15' 51.06"	23° 26' 13"	0 m 13 s
19	159° 47' 45"	-0.74"	161° 19' 60"	7° 53' 57"	1.0090003	15' 51.07"	23° 26' 13"	0 m 14 s
20	159° 50' 10"	-0.74"	161° 22' 15"	7° 53' 02"	1.0089903	15' 51.08"	23° 26' 13"	0 m 14 s
21	159° 52' 36"	-0.74"	161° 24' 31"	7° 52' 07"	1.0089803	15' 51.09"	23° 26' 13"	0 m 15 s
22	159° 55' 01"	-0.75"	161° 26' 47"	7° 51' 13"	1.0089702	15' 51.10"	23° 26' 13"	0 m 16 s
23	159° 57' 26"	-0.75"	161° 29' 03"	7° 50' 18"	1.0089602	15' 51.11"	23° 26' 13"	0 m 17 s
24	159° 59' 51"	-0.75"	161° 31' 18"	7° 49' 23"	1.0089502	15' 51.12"	23° 26' 13"	0 m 18 s

*) for mean equinox of date

DATA BULAN

Jam	Apparent Longitude	Apparent Latitude	Apparent Right Ascension	Apparent Declination	Horizontal Parallax	Semi Diameter	Angle Bright Limb	Fraction Illumination
0	325° 00' 38"	-4° 17' 23"	328° 47' 37"	-17° 13' 17"	0° 55' 26"	15' 06.28"	233° 22' 35"	0.98384
1	325° 31' 53"	-4° 18' 47"	329° 18' 46"	-17° 03' 56"	0° 55' 25"	15' 05.98"	232° 35' 37"	0.98481
2	326° 03' 07"	-4° 20' 11"	329° 49' 51"	-16° 54' 32"	0° 55' 24"	15' 05.69"	231° 46' 17"	0.98576
3	326° 34' 21"	-4° 21' 33"	330° 20' 52"	-16° 45' 03"	0° 55' 23"	15' 05.39"	230° 54' 21"	0.98666
4	327° 05' 33"	-4° 22' 53"	330° 51' 48"	-16° 35' 30"	0° 55' 21"	15' 05.10"	229° 59' 33"	0.98754
5	327° 36' 44"	-4° 24' 12"	331° 22' 41"	-16° 25' 52"	0° 55' 20"	15' 04.80"	229° 1' 34"	0.98837
6	328° 07' 54"	-4° 25' 30"	331° 53' 29"	-16° 16' 11"	0° 55' 19"	15' 04.51"	228° 0' 05"	0.98918
7	328° 39' 03"	-4° 26' 47"	332° 24' 12"	-16° 06' 25"	0° 55' 18"	15' 04.22"	226° 54' 42"	0.98995
8	329° 10' 11"	-4° 28' 02"	332° 54' 52"	-15° 56' 35"	0° 55' 17"	15' 03.93"	225° 45' 01"	0.99068
9	329° 41' 18"	-4° 29' 16"	333° 25' 27"	-15° 46' 42"	0° 55' 16"	15' 03.65"	224° 30' 32"	0.99138
10	330° 12' 24"	-4° 30' 28"	333° 55' 59"	-15° 36' 44"	0° 55' 15"	15' 03.36"	223° 10' 41"	0.99205
11	330° 43' 29"	-4° 31' 39"	334° 26' 26"	-15° 26' 42"	0° 55' 14"	15' 03.07"	221° 44' 51"	0.99268
12	331° 14' 33"	-4° 32' 49"	334° 56' 49"	-15° 16' 37"	0° 55' 13"	15' 02.79"	220° 12' 18"	0.99328
13	331° 45' 36"	-4° 33' 57"	335° 27' 08"	-15° 06' 28"	0° 55' 12"	15' 02.51"	218° 32' 15"	0.99384
14	332° 16' 38"	-4° 35' 03"	335° 57' 24"	-14° 56' 15"	0° 55' 11"	15' 02.23"	216° 43' 45"	0.99437
15	332° 47' 38"	-4° 36' 09"	336° 27' 35"	-14° 45' 59"	0° 55' 10"	15' 01.95"	214° 45' 46"	0.99487
16	333° 18' 38"	-4° 37' 13"	336° 57' 42"	-14° 35' 39"	0° 55' 09"	15' 01.67"	212° 37' 09"	0.99533
17	333° 49' 37"	-4° 38' 15"	337° 27' 45"	-14° 25' 15"	0° 55' 08"	15' 01.40"	210° 16' 35"	0.99576
18	334° 20' 35"	-4° 39' 16"	337° 57' 45"	-14° 14' 49"	0° 55' 07"	15' 01.12"	207° 42' 40"	0.99615
19	334° 51' 32"	-4° 40' 16"	338° 27' 40"	-14° 04' 18"	0° 55' 06"	15' 00.85"	204° 53' 51"	0.99651
20	335° 22' 27"	-4° 41' 14"	338° 57' 32"	-13° 53' 45"	0° 55' 05"	15' 00.57"	201° 48' 35"	0.99684
21	335° 53' 22"	-4° 42' 11"	339° 27' 20"	-13° 43' 08"	0° 55' 04"	15' 00.30"	198° 25' 17"	0.99713
22	336° 24' 16"	-4° 43' 07"	339° 57' 04"	-13° 32' 28"	0° 55' 03"	15' 00.03"	194° 42' 34"	0.99738
23	336° 55' 09"	-4° 44' 01"	340° 26' 45"	-13° 21' 44"	0° 55' 02"	14' 59.77"	190° 39' 18"	0.99761
24	337° 26' 00"	-4° 44' 53"	340° 56' 21"	-13° 10' 58"	0° 55' 01"	14' 59.50"	186° 14' 59"	0.99780

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DATA MATAHARI

Jam	Ecliptic Longitude *)	Ecliptic Latitude *)	Apparent Right Ascension	Apparent Declination	True Geocentric Distance	Semi Diameter	True Obliquity	Equation Of Time
0	160° 57' 55"	-0.79"	162° 25' 33"	7° 27' 25"	1.0087088	15' 51.34"	23° 26' 13"	0 m 37 s
1	161° 00' 21"	-0.79"	162° 27' 48"	7° 26' 30"	1.0086987	15' 51.35"	23° 26' 13"	0 m 38 s
2	161° 02' 46"	-0.79"	162° 30' 04"	7° 25' 35"	1.0086886	15' 51.36"	23° 26' 13"	0 m 39 s
3	161° 05' 11"	-0.79"	162° 32' 19"	7° 24' 40"	1.0086785	15' 51.37"	23° 26' 13"	0 m 39 s
4	161° 07' 36"	-0.79"	162° 34' 35"	7° 23' 45"	1.0086684	15' 51.38"	23° 26' 13"	0 m 40 s
5	161° 10' 02"	-0.79"	162° 36' 50"	7° 22' 50"	1.0086583	15' 51.39"	23° 26' 13"	0 m 41 s
6	161° 12' 27"	-0.79"	162° 39' 06"	7° 21' 55"	1.0086482	15' 51.40"	23° 26' 13"	0 m 42 s
7	161° 14' 52"	-0.79"	162° 41' 21"	7° 20' 59"	1.0086381	15' 51.41"	23° 26' 13"	0 m 43 s
8	161° 17' 17"	-0.79"	162° 43' 37"	7° 20' 04"	1.0086280	15' 51.42"	23° 26' 13"	0 m 44 s
9	161° 19' 43"	-0.79"	162° 45' 52"	7° 19' 09"	1.0086179	15' 51.43"	23° 26' 13"	0 m 44 s
10	161° 22' 08"	-0.79"	162° 48' 08"	7° 18' 14"	1.0086078	15' 51.44"	23° 26' 13"	0 m 45 s
11	161° 24' 33"	-0.79"	162° 50' 23"	7° 17' 19"	1.0085977	15' 51.45"	23° 26' 13"	0 m 46 s
12	161° 26' 58"	-0.80"	162° 52' 38"	7° 16' 24"	1.0085876	15' 51.46"	23° 26' 13"	0 m 47 s
13	161° 29' 24"	-0.80"	162° 54' 54"	7° 15' 28"	1.0085775	15' 51.47"	23° 26' 13"	0 m 48 s
14	161° 31' 49"	-0.80"	162° 57' 09"	7° 14' 33"	1.0085674	15' 51.48"	23° 26' 13"	0 m 48 s
15	161° 34' 14"	-0.80"	162° 59' 25"	7° 13' 38"	1.0085572	15' 51.49"	23° 26' 13"	0 m 49 s
16	161° 36' 39"	-0.80"	163° 01' 40"	7° 12' 43"	1.0085471	15' 51.50"	23° 26' 13"	0 m 50 s
17	161° 39' 05"	-0.80"	163° 03' 56"	7° 11' 47"	1.0085370	15' 51.51"	23° 26' 13"	0 m 51 s
18	161° 41' 30"	-0.80"	163° 06' 11"	7° 10' 52"	1.0085269	15' 51.52"	23° 26' 13"	0 m 52 s
19	161° 43' 55"	-0.80"	163° 08' 26"	7° 09' 57"	1.0085167	15' 51.53"	23° 26' 13"	0 m 53 s
20	161° 46' 21"	-0.80"	163° 10' 42"	7° 09' 01"	1.0085066	15' 51.54"	23° 26' 13"	0 m 53 s
21	161° 48' 46"	-0.80"	163° 12' 57"	7° 08' 06"	1.0084965	15' 51.55"	23° 26' 13"	0 m 54 s
22	161° 51' 11"	-0.80"	163° 15' 13"	7° 07' 11"	1.0084863	15' 51.55"	23° 26' 13"	0 m 55 s
23	161° 53' 36"	-0.80"	163° 17' 28"	7° 06' 15"	1.0084762	15' 51.56"	23° 26' 13"	0 m 56 s
24	161° 56' 02"	-0.79"	163° 19' 43"	7° 05' 20"	1.0084660	15' 51.57"	23° 26' 13"	0 m 57 s

*) for mean equinox of date

DATA BULAN

Jam	Apparent Longitude	Apparent Latitude	Apparent Right Ascension	Apparent Declination	Horizontal Parallax	Semi Diameter	Angle Bright Limb	Fraction Illumination
0	349° 41' 47"	-4° 58' 46"	352° 30' 16"	-8° 39' 23"	0° 54' 39"	14' 53.62"	96° 9' 23"	0.99238
1	350° 12' 15"	-4° 59' 02"	352° 58' 33"	-8° 27' 37"	0° 54' 39"	14' 53.40"	94° 52' 11"	0.99175
2	350° 42' 41"	-4° 59' 18"	353° 26' 48"	-8° 15' 50"	0° 54' 38"	14' 53.18"	93° 40' 42"	0.99108
3	351° 13' 07"	-4° 59' 31"	353° 54' 60"	-8° 04' 01"	0° 54' 37"	14' 52.96"	92° 34' 20"	0.99038
4	351° 43' 32"	-4° 59' 44"	354° 23' 09"	-7° 52' 10"	0° 54' 36"	14' 52.74"	91° 32' 37"	0.98965
5	352° 13' 56"	-4° 59' 55"	354° 51' 16"	-7° 40' 18"	0° 54' 35"	14' 52.53"	90° 35' 05"	0.98889
6	352° 44' 18"	-5° 00' 04"	355° 19' 21"	-7° 28' 24"	0° 54' 35"	14' 52.31"	89° 41' 20"	0.98810
7	353° 14' 40"	-5° 00' 12"	355° 47' 23"	-7° 16' 29"	0° 54' 34"	14' 52.10"	88° 51' 03"	0.98728
8	353° 45' 01"	-5° 00' 19"	356° 15' 23"	-7° 04' 33"	0° 54' 33"	14' 51.90"	88° 3' 54"	0.98643
9	354° 15' 22"	-5° 00' 24"	356° 43' 20"	-6° 52' 35"	0° 54' 32"	14' 51.69"	87° 19' 37"	0.98554
10	354° 45' 41"	-5° 00' 28"	357° 11' 16"	-6° 40' 36"	0° 54' 32"	14' 51.49"	86° 37' 58"	0.98462
11	355° 15' 59"	-5° 00' 31"	357° 39' 09"	-6° 28' 36"	0° 54' 31"	14' 51.28"	85° 58' 43"	0.98368
12	355° 46' 17"	-5° 00' 32"	358° 06' 60"	-6° 16' 34"	0° 54' 30"	14' 51.08"	85° 21' 42"	0.98270
13	356° 16' 33"	-5° 00' 31"	358° 34' 48"	-6° 04' 32"	0° 54' 29"	14' 50.89"	84° 46' 43"	0.98169
14	356° 46' 49"	-5° 00' 29"	359° 02' 35"	-5° 52' 28"	0° 54' 29"	14' 50.69"	84° 13' 37"	0.98065
15	357° 17' 04"	-5° 00' 26"	359° 30' 20"	-5° 40' 23"	0° 54' 28"	14' 50.50"	83° 42' 17"	0.97958
16	357° 47' 18"	-5° 00' 22"	359° 58' 03"	-5° 28' 18"	0° 54' 27"	14' 50.31"	83° 12' 34"	0.97848
17	358° 17' 31"	-5° 00' 16"	0° 25' 44"	-5° 16' 11"	0° 54' 26"	14' 50.12"	82° 44' 21"	0.97735
18	358° 47' 43"	-5° 00' 08"	0° 53' 23"	-5° 04' 03"	0° 54' 26"	14' 49.94"	82° 17' 33"	0.97619
19	359° 17' 55"	-4° 59' 59"	1° 20' 60"	-4° 51' 55"	0° 54' 25"	14' 49.75"	81° 52' 03"	0.97499
20	359° 48' 05"	-4° 59' 49"	1° 48' 35"	-4° 39' 46"	0° 54' 24"	14' 49.57"	81° 27' 47"	0.97377
21	0° 18' 15"	-4° 59' 37"	2° 16' 09"	-4° 27' 35"	0° 54' 24"	14' 49.39"	81° 4' 40"	0.97252
22	0° 48' 24"	-4° 59' 24"	2° 43' 41"	-4° 15' 25"	0° 54' 23"	14' 49.22"	80° 42' 37"	0.97124
23	1° 18' 32"	-4° 59' 10"	3° 11' 11"	-4° 03' 13"	0° 54' 23"	14' 49.04"	80° 21' 35"	0.96993
24	1° 48' 39"	-4° 58' 54"	3° 38' 40"	-3° 51' 01"	0° 54' 22"	14' 48.87"	80° 1' 31"	0.96859

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DATA MATAHARI

Jam	Ecliptic Longitude *)	Ecliptic Latitude *)	Apparent Right Ascension	Apparent Declination	True Geocentric Distance	Semi Diameter	True Obliquity	Equation Of Time
0	161° 56' 02"	-0.79"	163° 19' 43"	7° 05' 20"	1.0084660	15' 51.57"	23° 26' 13"	0 m 57 s
1	161° 58' 27"	-0.79"	163° 21' 59"	7° 04' 25"	1.0084559	15' 51.58"	23° 26' 13"	0 m 58 s
2	162° 00' 52"	-0.79"	163° 24' 14"	7° 03' 29"	1.0084458	15' 51.59"	23° 26' 13"	0 m 58 s
3	162° 03' 18"	-0.79"	163° 26' 29"	7° 02' 34"	1.0084356	15' 51.60"	23° 26' 13"	0 m 59 s
4	162° 05' 43"	-0.79"	163° 28' 45"	7° 01' 39"	1.0084255	15' 51.61"	23° 26' 13"	1 m 00 s
5	162° 08' 08"	-0.79"	163° 30' 60"	7° 00' 43"	1.0084153	15' 51.62"	23° 26' 13"	1 m 01 s
6	162° 10' 34"	-0.79"	163° 33' 15"	6° 59' 48"	1.0084052	15' 51.63"	23° 26' 13"	1 m 02 s
7	162° 12' 59"	-0.79"	163° 35' 31"	6° 58' 52"	1.0083950	15' 51.64"	23° 26' 13"	1 m 03 s
8	162° 15' 24"	-0.79"	163° 37' 46"	6° 57' 57"	1.0083848	15' 51.65"	23° 26' 13"	1 m 03 s
9	162° 17' 50"	-0.79"	163° 40' 01"	6° 57' 01"	1.0083747	15' 51.66"	23° 26' 13"	1 m 04 s
10	162° 20' 15"	-0.79"	163° 42' 17"	6° 56' 06"	1.0083645	15' 51.67"	23° 26' 13"	1 m 05 s
11	162° 22' 40"	-0.79"	163° 44' 32"	6° 55' 10"	1.0083543	15' 51.68"	23° 26' 13"	1 m 06 s
12	162° 25' 05"	-0.79"	163° 46' 47"	6° 54' 15"	1.0083442	15' 51.69"	23° 26' 13"	1 m 07 s
13	162° 27' 31"	-0.79"	163° 49' 02"	6° 53' 19"	1.0083340	15' 51.70"	23° 26' 13"	1 m 07 s
14	162° 29' 56"	-0.78"	163° 51' 18"	6° 52' 24"	1.0083238	15' 51.71"	23° 26' 13"	1 m 08 s
15	162° 32' 22"	-0.78"	163° 53' 33"	6° 51' 28"	1.0083136	15' 51.72"	23° 26' 13"	1 m 09 s
16	162° 34' 47"	-0.78"	163° 55' 48"	6° 50' 33"	1.0083035	15' 51.73"	23° 26' 13"	1 m 10 s
17	162° 37' 12"	-0.78"	163° 58' 04"	6° 49' 37"	1.0082933	15' 51.74"	23° 26' 13"	1 m 11 s
18	162° 39' 38"	-0.78"	164° 00' 19"	6° 48' 42"	1.0082831	15' 51.75"	23° 26' 13"	1 m 12 s
19	162° 42' 03"	-0.78"	164° 02' 34"	6° 47' 46"	1.0082729	15' 51.76"	23° 26' 13"	1 m 12 s
20	162° 44' 28"	-0.78"	164° 04' 49"	6° 46' 51"	1.0082627	15' 51.77"	23° 26' 13"	1 m 13 s
21	162° 46' 54"	-0.78"	164° 07' 05"	6° 45' 55"	1.0082525	15' 51.78"	23° 26' 13"	1 m 14 s
22	162° 49' 19"	-0.77"	164° 09' 20"	6° 44' 59"	1.0082423	15' 51.79"	23° 26' 13"	1 m 15 s
23	162° 51' 44"	-0.77"	164° 11' 35"	6° 44' 04"	1.0082321	15' 51.79"	23° 26' 13"	1 m 16 s
24	162° 54' 10"	-0.77"	164° 13' 50"	6° 43' 08"	1.0082219	15' 51.80"	23° 26' 13"	1 m 17 s

*) for mean equinox of date

DATA BULAN

Jam	Apparent Longitude	Apparent Latitude	Apparent Right Ascension	Apparent Declination	Horizontal Parallax	Semi Diameter	Angle Bright Limb	Fraction Illumination
0	1° 48' 39"	-4° 58' 54"	3° 38' 40"	-3° 51' 01"	0° 54' 22"	14' 48.87"	80° 1' 31"	0.96859
1	2° 18' 46"	-4° 58' 37"	4° 06' 08"	-3° 38' 49"	0° 54' 21"	14' 48.70"	79° 42' 21"	0.96722
2	2° 48' 51"	-4° 58' 18"	4° 33' 34"	-3° 26' 35"	0° 54' 21"	14' 48.54"	79° 24' 01"	0.96582
3	3° 18' 56"	-4° 57' 58"	5° 00' 58"	-3° 14' 22"	0° 54' 20"	14' 48.37"	79° 6' 30"	0.96440
4	3° 49' 00"	-4° 57' 37"	5° 28' 21"	-3° 02' 08"	0° 54' 19"	14' 48.21"	78° 49' 44"	0.96294
5	4° 19' 03"	-4° 57' 14"	5° 55' 43"	-2° 49' 53"	0° 54' 19"	14' 48.05"	78° 33' 42"	0.96146
6	4° 49' 06"	-4° 56' 50"	6° 23' 03"	-2° 37' 38"	0° 54' 18"	14' 47.90"	78° 18' 21"	0.95994
7	5° 19' 08"	-4° 56' 24"	6° 50' 23"	-2° 25' 23"	0° 54' 18"	14' 47.74"	78° 3' 39"	0.95840
8	5° 49' 09"	-4° 55' 57"	7° 17' 41"	-2° 13' 07"	0° 54' 17"	14' 47.59"	77° 49' 35"	0.95683
9	6° 19' 09"	-4° 55' 29"	7° 44' 58"	-2° 00' 52"	0° 54' 17"	14' 47.44"	77° 36' 06"	0.95523
10	6° 49' 08"	-4° 54' 60"	8° 12' 14"	-1° 48' 36"	0° 54' 16"	14' 47.30"	77° 23' 11"	0.95360
11	7° 19' 07"	-4° 54' 29"	8° 39' 29"	-1° 36' 20"	0° 54' 16"	14' 47.15"	77° 10' 48"	0.95195
12	7° 49' 05"	-4° 53' 56"	9° 06' 43"	-1° 24' 03"	0° 54' 15"	14' 47.01"	76° 58' 57"	0.95026
13	8° 19' 02"	-4° 53' 23"	9° 33' 56"	-1° 11' 47"	0° 54' 15"	14' 46.88"	76° 47' 35"	0.94855
14	8° 48' 58"	-4° 52' 48"	10° 01' 08"	0°-59' 31"	0° 54' 14"	14' 46.74"	76° 36' 42"	0.94681
15	9° 18' 54"	-4° 52' 12"	10° 28' 19"	0°-47' 15"	0° 54' 14"	14' 46.61"	76° 26' 17"	0.94504
16	9° 48' 49"	-4° 51' 34"	10° 55' 30"	0°-34' 59"	0° 54' 13"	14' 46.48"	76° 16' 18"	0.94325
17	10° 18' 43"	-4° 50' 55"	11° 22' 40"	0°-22' 43"	0° 54' 13"	14' 46.36"	76° 6' 44"	0.94143
18	10° 48' 37"	-4° 50' 15"	11° 49' 49"	0°-10' 27"	0° 54' 12"	14' 46.23"	75° 57' 35"	0.93958
19	11° 18' 30"	-4° 49' 33"	12° 16' 58"	0° 01' 49"	0° 54' 12"	14' 46.11"	75° 48' 49"	0.93770
20	11° 48' 22"	-4° 48' 50"	12° 44' 06"	0° 14' 04"	0° 54' 11"	14' 45.99"	75° 40' 26"	0.93580
21	12° 18' 14"	-4° 48' 06"	13° 11' 13"	0° 26' 20"	0° 54' 11"	14' 45.88"	75° 32' 25"	0.93387
22	12° 48' 05"	-4° 47' 21"	13° 38' 20"	0° 38' 34"	0° 54' 11"	14' 45.77"	75° 24' 46"	0.93192
23	13° 17' 55"	-4° 46' 34"	14° 05' 27"	0° 50' 49"	0° 54' 10"	14' 45.66"	75° 17' 27"	0.92993
24	13° 47' 45"	-4° 45' 46"	14° 32' 33"	1° 03' 03"	0° 54' 10"	14' 45.55"	75° 10' 27"	0.92793

KEMENTRIAN AGAMA
MADRASAH ALIYAH NEGERI
SURAKARTA

LEMBAR DISPOSISI

Indeks Berkas : –	Kode: 407

Tanggal/Nomor	: 27 Juli 2020 / 407
Asal	: Fakultas Syari'ah dan Hukum, UIN Walisongo, Semarang
Isi Ringkas	: Permohonan Izin Penelitian a.n. Muhammad Fiqhussunnah Al Khoiron
Diterima Tanggal	: 03 Agustus 2020

Tanggal Penyelesaian :

Isi Disposisi :	Diteruskan Kepada :
Harap di TL isi surat ini, 04/08 '21	Abdul Mutholib, M.Ag

Sesudah digunakan segera dikembalikan

Kepada : ....
Tanggal : ....

Diberikan ijin utk menggunakan lab. keagamaan

Suharno.

CURRICULUM VITAE

PERSONAL IDENTITY

Name	: Muhamad Fiqhussunnah Al Khoiron
Place and date of birth	: Boyolali, 4 Desember 1999
Gender	: Male
Religion	: Islam
Nationality	: Indonesia
Address	: Wonorejo RT 03 RW 06 Sukorejo Musuk Boyolali
Phone Number	: 082241264468
E-mail	: mfiqhussunnah@gmail.com

FORMAL EDUCATION

1. MI Badrissalam Sukorejo
2. MtsN Boyolali
3. MAPK MAN I Surakarta

NONFORMAL EDUCATION

1. Pesantren Life Skill Daarun Najaah Semarang
2. XL Future Leaders Program batch 7