AN ALGORITHM ANALYSIS OF THE LUNAR ECLIPSE CALCULATION IN THE BOOK RISĀLAH AZ-ZAIN BY IBN YA'QŪB AL-BATĀWY

UNDERGRADUATE THESIS

Submitted to Faculty of Sharia and Law in Partial of the Requirement for the Degree of Bachelor of Law in Department of Islamic Astronomy

Written by:

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FACULTY OF SHARIA AND LAW
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SEMARANG

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MOTTO

هُوَ ٱلَّذِى جَعَلَ ٱلشَّمۡسَ ضِيَآءً وَٱلۡقَمَرَ نُورًا وَقَدَّرَهُۥ مَنَازِلَ لِتَعۡلَمُواْ عَدَدَ
ٱلسِّنِينَ وَٱلۡحِسَابَۚ مَا خَلَقَ ٱللَّهُ ذَٰلِكَ إِلَّا بِٱلۡحَقِّۚ يُفَصِّلُ ٱلۡأَيَٰتِ لِقَوۡمٍ
يَعۡلَمُونَ

(سُوْرَةُ يُونس:٥)

"It is He who made the Sun to be a shining glory and the Moon to be a light (of beauty), and measured out the stages for it, that we might know the number of years and the count (of time). Nowise did Allah create this but in truth and righteousness. (Thus) both explains His signs in detail for those who know."
(Q. S. *Yunus*: 5)[1]

[1] Abdullah Yusuf Ali, *The Holy Quran English Translation of the Meaning and Commentary,* (Medina, Saudi Arabia: King Fahd Printing Complex, 1991), 548.

DEDICATION

All the praises and thanks be to Allah SWT, the lord of the world

This thesis is dedicated to:

My beloved parents, Mr. Idrawedi and Mrs. Yelli who always pray, support, and devote their love to me. Thank you for your uncountable efforts and contributions. I love you 3000.

My beloved brother and sister; Hijratul Hanif Idra, Nurul Hafizhah Idra, and Muhammad Mufid Idra.

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All of my friends, especially EXCELLENT 20, who encourage me during a hard time and make everything better.

Those people who appreciate and encourages this undergraduate thesis

DECLARATION

With full honesty and responsibility, the author states that this work does not contain material that has been written by someone else or published. Likewise, this work does not contain any other people's thought, except the information contained in the references that are used as reference material.

Semarang, June 7[rd] 2021

Declarator

Rohadatul 'Aisy Idra

1702046108

TRANSLITERATION[2]

I. Single Consonant

Letter	Name	Romanization	Letter	Name	Romanization
ء	hamzah	’	ظ	ẓā’	ẓ
ا	alif	ā	ع	‘ayn	‘
ب	bā’	b	غ	ghayn	gh (g̲h̲)
ت	tā’	t	ف	fā’	f
ث	thā’	th (th)	ق	qāf	q
ج	jīm	j	ك	kāf	k
ح	ḥā’	ḥ	ل	lām	l
خ	khā’	kh (k̲h̲)	م	mīm	m
د	dāl	d	ن	nūn	n
ذ	dhāl	dh (d̲h̲)	ه	hā’	h
ر	rā’	r	و	wāw	w; ū
ز	zayn/zāy	z	ي	yā’	y; ī
س	sīn	s	آ	alif maddah	ā, ’ā
ش	shīn	sh (s̲h̲)	ة	tā’ marbūṭah	h; t
ص	ṣād	ṣ	ال	alif lām	al-
ض	ḍād	ḍ	ى	alif maqṣūrah	á
ط	ṭā’	ṭ			

[2] This undergraduate thesis is using ALA-LC (American Library Association – Library of Congress) romanization, which is used internationally in scientific publication by Arabist.

II. Double Consonant

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

رَبَّكَ is written rabbaka

الحَدّ 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:

قالَ 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' Marbūthah (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

   اَلتوبةَ is written as al-taubah

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

   روضة اَلاطفالَ is written as rauḍah al-aṭfāl

   But if they are read a unit, it must be written as t. For example:

   روضة اَلاطفال is written as rauḍatul aṭfāl

V. Article Alif +Lam

1. Article (ال) that is followed by *hurūf shamsiyah* is written as how it is read and separated by stripe (-). For example:

   الرحيم is written as *ar-Raḥīmu*

   السيدَ is written as *as-sayyidu*

   اَلشمسَ is written as *asy-shamsu*

2. Article (ال) that is followed by *hurūf 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 اَلرازقين is written as *khair rāziqīn or khairurrāziqīn.*

ABSTRACT

The lunar eclipse reckoning algorithm used in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy uses the Jean Meus Algorithm, but there are some formulas that are different such as calculating the value of K (estimated year of the eclipse), simplification of the formula F (argument for the latitude of the Moon), formula for calculating the value of A (additional correction to get the value of C), correction formula to determine the value of C (time of maximum eclipse), and determination of *Pasaran* when the eclipse occurs.

This research is a type of library research. The analysis process uses descriptive analysis. The primary data used is the book *Risālah az-Zain* and direct interviews with the author of the book, namely Ibn Ya'qūb al-Batāwy. Secondary data is in the form of documents related to lunar eclipses. The purpose of this study was to determine the lunar eclipse reckoning algorithm in the book *Risālah az-Zain* and to determine the accuracy of the reckoning by analyzing the eclipse reckoning data of Jean Meeus in *Astronomical Algorithms* and NASA.

This research has 2 results: First, the lunar eclipse reckoning algorithm in the Risālah az-Zain book is classified as *hisāb haqiqi contemporary*, this can be seen from the astronomical data used using the latest data and using the latest algorithms. This lunar eclipse reckoning algorithm is based on Jean Meeus's Algorithm in the book Astronomical Algorithms and uses Julian day, the new epoch of 2000, and Danjon's rules.

Second, the lunar eclipse reckoning algorithm has good accuracy because the result of data from the calculation of the lunar eclipse of Risālah az-Zain and Jean Meeus differs slightly with the largest average difference of -0:01:21 in the phase of U1, maximum of the eclipse, and P4. The smallest difference is -0:01:12 in the phase of P1, U1, U2, U4 and P4. The result of data from the calculation of Risālah az-Zain's lunar eclipse with NASA is slightly different with the largest average difference of -00:05:48 in U1 phase. The smallest difference is 00:00:00 / has no difference in U4 phase.

Lunar eclipse calculation algorithm in book Risālah az-Zain needs some additions, such as: calculations to find out the area and state of a place during a lunar eclipse as done by NASA and the inclusion of a formula for calculating the value of E (eccentricity value of the Earth's orbit around the Sun), JDE WD (Julian date adjusted to the time of the area), and Z (value to determine the days and markets when the eclipse occurs) in chapter *al-Kusūfaini* (Two Eclipses).

Keyword: Lunar Eclipse, Risālah az-Zain, Ibn Ya'qūb al-Batāwy, Astronomical Algorithm, Jean Meuss, NASA.

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1702046108

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CHAPTER I
INTRODUCTION

A. Background of Study

The Book *Risālah az-Zain* is the second book by Ibn Ya'qūb al-Batāwy. This book discusses astronomy calculations like determining the beginning of the lunar month, the reckoning of the lunar eclipse, and the reckoning of the solar eclipse. This book has been compiled using a modern computation system with a Microsoft Excel[1] media approach. This book enriches the science of astronomy using contemporary reckoning, especially Microsoft Excel, which is a popular application among astronomy experts.

This book discusses the reckoning of lunar eclipses. The reckoning of a lunar eclipse is carried out to determine when a solar or lunar eclipse occurs. This book is intended to make it easier for Muslims to perform *khusūf al-Qamar* prayers (lunar eclipse prayers) or *kusūf ash-Shams* (solar eclipse prayers).[2] Many Indonesian scholars have enriched the treasury of eclipse reckoning, including KH. Abdul Djalil with his book *Fatḥ Raūf al-Mannan*, Manshur al-Battawiy

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[1]Microsoft Excel is spreadsheet developed by Microsoft in the form of program or application. Ms. Excel is a part of the Microsoft Office installation package for Windows, macOS, Android and iOS. It functions to process numbers and data using a spreadsheet consisting of rows and columns to execute commands. It features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications (VBA).

[2]Direktorat Jenderal Badan Peradilan Agama, *Almanak Hisab Rukyah,* (Jakarta: Mahkamah Agung RI, 2007), 169.

with his book *Sulām an-Nayyirain*, KH. Ahmad Zubair Umar al-Jaelany with his work *Khulāṣah al-Wāfiyah*, KH. Noor Ahmad SS with his work on the books of *Nūr al-Anwār* and *Shams al-Hilāl*.[3]

The phenomenon caused by the Sun is a form of the greatness of Allah SWT. It was created as one of the celestial bodies that can produce light and produce a source of energy that is useful for life in the universe. It also becomes a time guide for humans and animals with its bright light. Other celestial bodies can also be blocked so that a cosmic phenomenon known as an eclipse occurs, which is a time for worshipping the Almighty. [4]

Besides the Sun, the Moon is the most conspicuous celestial body, owing to its small distance from the Earth. The near equality in the apparent sizes of Sun and Moon arises from the exciting circumstance that the Sun, while it is about 400 times as great in diameter as the Moon, is also about that many times as far away.[5]

The word eclipse in English is known as "Eclipse"[6] and in Arabic it is known as "*Kusūf* or *Khusūf*",[7] while in

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[3]Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan Dalam Kitab *Maslak Al-Qāṣid Ilā 'Amal Ar-Rāṣid* Karya Kh. Ahmad Ghozali Muhammad Fathullah", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2015), 3.

[4]Muhyiddin Khazin, *Kamus Ilmu Falak*, (Yogyakarta: Buana Pustaka, 2005), 23.

[5] Robert H. Baker, *Astronomy,* (Canada: D. Van Nostrand Company, 1955), 133.

[6]In English it is called "eclipse" and in Latin it is called "ekleipsis". This term is used in general, both solar and lunar eclipses. However, in its mention, we get two terms Eclipse of the Sun for a solar eclipse and eclipse of the moon for a lunar eclipse and the term Solar Eclipse is also used for a solar eclipse and

Latin it is called *"Ekleipsis"*.[8] The terms *Kusūf* and *Khusūf* can be used to refer to solar and lunar eclipses. The word "*Kusūf*" is better known for referring to a solar eclipse, while the word "*Khusūf*" for a lunar eclipse. *Kusūf* means "covering", this describes the natural phenomenon that the Moon covers the Sun (when viewed from Earth). Meanwhile, *Khusūf* means "entering", describing the existence of natural phenomena that the Moon enters the Earth's shadow, resulting in a lunar eclipse.[9]

A solar eclipse (*kusūf asy*-*Shams*) occurs during *ijtimā'*[10], while a lunar eclipse (*khusūf al*-*Qamar*) occurs at *istiqbāl*[11] time. According to A. Katsir, *kusūf* (solar eclipse) occurs because the Moon crosses the shadow of the Sun's cone. A partial eclipse will happen if only a part of it is passed, and a total eclipse will happen if it is closed perfectly. On the other hand, *khusūf* (lunar eclipse) where the light gets reflected from the Sun's rays is traversed by the Earth until it is covered by light so that there is a lunar eclipse. If it is closed a little, there is a partial eclipse and if it

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lunar eclipse for a lunar eclipse. See Ahmad Izzuddin, *Ilmu Falak Praktis: Metode Hisab-Rukyat Praktis dan Solusi Permasalahannya*, (Semarang: Pustaka Rizki Putra, 2012), 105.

[7] Muhyidin Khazin, *Ilmu Falak dalam Teori dan Praktik,* (Yogyakarta: Buana Pustaka, 2008), 187.

[8] Ahmad Izzuddin, *Ilmu Falak Praktis*, 105.

[9] Muhyidin Khazin, *Ilmu Falak dalam Teori dan Praktik*, 187.

[10] *Ijtimā'* means "gathering" or "together", when the Sun and Moon are in one astronomical longitude. In astronomy it is known as the Conjunction. Astronomers use conjuction as a change in the qomariyah month, also known as the New Moon. See Muhyiddin Khazin, *Kamus, 32.*

[11] *Istiqbāl* means "face to face", when the Sun and Moon are facing each other, so that the astronomical longitudes of the two are 180° apart. In astronomy it is known as the Opposition. See Muhyiddin Khazin, *Kamus,* 38.

is closed a lot, there is a total eclipse. At first glance, it looks the same thing, but *kusūf* occurs at a certain *ijtimā*', while *khusūf* occurs at a certain *istiqbāl* time. The incident happened around February-March-April or August-September-October when *ijtimā*' or *istiqbāl* fell in the sixth months, followed by three months. Therefore, it is more accessible to know the possibilities by using the data.[12]

At certain times, during the full moon, there will be a lunar eclipse. The occurrence of the lunar eclipse is of course inseparable from the three celestial bodies, the Moon, Earth, and the Sun, when the three celestial bodies are in a straight line. There are two kinds of eclipses, namely a lunar eclipse and a solar eclipse. Lunar eclipses occur several times a year when the Moon is full. On the other hand, a solar eclipse occurs when the new moon comes or at the beginning of the month.[13]

A lunar eclipse occurs when the Moon is in Sun's opposition and is located close to the axis of the Earth's shadow. A lunar eclipse will only happen during the full moon, where the Moon at that time in its circulation is cutting the ecliptic plane (the Moon's circulation has a tilt of about 5º to the ecliptic plane).[14]

A lunar eclipse only occurs during the full moon, when Earth's position is between the Moon and the Sun. At

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[12]A. Kadir, *Formula Baru Ilmu Falak Panduan Lengkap & Praktis*, (Jakarta: Amzah, 2012), 203-204.

[13] Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan", 5.

[14]Badan Hisab Dan Rukyat Dep. Agama, *Almanak Hisab Rukyat*, (Jakarta: Proyek Pembinaan Badan Peradilan Agama Islam, 1998), 145.

that time, the Earth's shadow covers the Moon so that the Full Moon becomes dark and reddish. This lunar eclipse can last quite a while, sometimes reaching several hours.[15]

Several methods are used to calculate the lunar eclipse, namely: the method *hisāb' urfiy*,[16] where the date calculation system is based on the average circulation of the Moon around the Earth. Therefore, the average age of the month can also be applied. This reckoning method is only used to validate *mu'āmalāh* internationally, not for the implementation of worship in *syar'i*. The method of *hisāb haqīqī*[17], this calculation system is more advanced, based on the actual circulation of the Moon and Earth. The age of each month is neither constant nor irregular but depends on the new moon's position at the beginning of the month. The system of essential reckoning is grouped into three[18], namely: *hisāb haqīqī taqrībiy*[19], *hisāb haqīqī tahqīqīy*[20], and *hisāb haqīqī contemporary.*[21]

[15] A. Kadir, *Formula Baru Ilmu Falak,* 209.

[16] Susiknan Azhari, *Ensiklopedi Hisab Rukyah,* (Yogyakarta: Pustaka Pelajar, 2008), cet. 2, 79.

[17] Susiknan Azhari, *Ensiklopedi,* 78.

[18]Ahmad Izzuddin, *Fiqih Hisab Rukyah (Menyatukan NU & MUHAMMADIYAH Dalam Penentuan Awal Ramadhan, Idul Fitri, dan Idul Adha),* (Jakarta: Penerbit Erlangga, 2007), 7.

[19] *Hisāb Haqīqī Taqrībi* is is the calculation of the position of celestial bodies based on the average motion of celestial bodies so that the results are estimates or approach the truth. See Muhyiddin Khazin, *Kamus,* 29.

[20] *Hisāb Haqīqī Tahqīqī* is the calculation of the position of celestial bodies based on the actual motion of celestial bodies, so the results are quite accurate. See Muhyiddin Khazin, *Kamus,* 29.

[21] *Hisāb Haqīqī* Contemporer is a calculation that has used computerized media and sophisticated equipment in theory and application such as: compass, theodolite, GPS, and so on. In calculating the computation data using very

The method of *hisāb haqīqī* is grouped into three[22], as follows:

1. *Hisāb Haqīqī Taqrībīy* is the calculation of uses data from the Moon and the Sun based on Ulugh Beikh's calculation data and tables with a simple process and calculation system (without using the spherical triangle system theory).
2. *Hisāb Haqīqī Tahqīqīy* uses corrected tables and uses a relatively more complicated calculation than the *hisāb haqīqī taqrībi* because it uses the spherical triangle theory.
3. *Hisāb Haqīqī* Contemporer has used computerized media and sophisticated equipment such as compass, theodolite, GPS, etc. Data calculation using a highly complex formula. Besides using the spherical triangle formula, all the computation data is programmed through a computerized device to minimalize errors in calculations and the accuracy of the calculation results according to the facts in the place of observation.

Hisāb Haqīqī Contemporary is the most popular reckoning and is widely used by astronomers today. The essential contemporary analysis itself is contained in various models. Some are in the form of data presented in table forms such as *Astronomical Almanac* and *Ephemeris*, while

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complicated formulas and using the theory of spherical measurement, all the computation data is programmed through a computerized device to minimize errors in calculations and the accuracy of the calculation results is in accordance with the reality at the observation site.

[22] Ahmad Izzuddin, *Fiqih*, 7.

others are in the form of a computer program such as Ing Khafid's *Mawāqīt*.[23]

The accuracy in calculating the lunar eclipse will serve as a guide in performing the eclipse prayer. Therefore, Ibn Ya'qūb al-Batāwy in his work, the book *Risālah az-Zain*, applies a *hisāb haqiqi contemporary* system which in his calculations uses the Microsoft Excel approach. Each calculation is entered into the formulas via computer devices that have been adjusted to new developments and discoveries so that errors in calculations can be minimized. Using the Microsoft Excel application is strengthened because the programming language is simple, easy to learn by beginners, and accurate.

The formula for calculating lunar eclipses in *Risālah az-Zain*'s book was inspired by Jean Meeus's calculation of lunar eclipses in his *Astronomical Algorithm*. There are similarities and some minor differences. These equations can be seen in the use of formulas and the data sources used. This is what causes the calculation results of lunar eclipses in the *Risālah az-Zain* book to only have a slight difference with the *Astronomical Algorithm* book.

The following is an example of the calculation results of the total lunar eclipse on May 26, 2021 in the book *Risālah az-Zain* and Jean Meeus's *Astronomical Algorithm*, and the results of this calculation are tested for accuracy with

[23] Sukarni, "Metode Hisab Gerhana Bulan Ahmad Ghozali dalam Kitab Irsyad al-Murid", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2014), 79.

the results of NASA's lunar eclipse calculation which is a credible source that has the highest level of accuracy among contemporary calculations:

Fase Gerhana	*Risālah az-Zain* (UT)	Jean Meeus (UT)	NASA (UT)
P1	08:49:24	8:48:12	08:47:39
U1	09:46:32	9:45:20	09:44:57
U2	11:14:05	11:12:53	11:11:25
Maximum of the Eclipse	11:19:44	11:18:31	11:18:40
U3	11:25:22	11:24:09	11:25:55
U4	12:52:55	12:51:43	12:52:22
P4	13:50:03	13:48:51	13:49:41

Table 1.1 Calculation results of lunar eclipses in the Risālah az-Zain, Jean Meeus's Astronomical Algorithm and NASA.

Based on the background above, the authors conducted further research on reckoning the lunar eclipse used in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy to get the accuracy of the reckoning method. Therefore, the writer intends to do research and lift the thesis entitled "An Algorithm Analysis of the Lunar Eclipse Calculation in the Book *Risālah az-Zain* By Ibn Ya'qūb al-Batāwy"

B. Research Question

Based on the description of the background of the problem above, the issues that the author will raise to be the main problem in this thesis are:

1. How is the calculation method for determining the lunar eclipse in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy?
2. How is the accuracy of the calculation method of the lunar eclipse in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy?

C. Objective of Study

Due to the basis of the above issues, the objectives to be achieved in this study are as follows:

1. To describe and know the calculation method of the lunar eclipse in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy.
2. To explain and evaluate the level of accuracy of the results of the calculation method of the lunar eclipse in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy.

D. Significance of Study

The benefits of this research are:

1. Enrich the scientific treasures of Muslims, especially those in Indonesia, regarding determining a lunar eclipse.
2. Gain insight into understanding the method of determining a lunar eclipse.
3. Become scientific research that can be used as an information and a reference for all people, astronomers, and researchers in the future.

E. Literature Review

Based on the literature review and the search that the author has done, the author knows the previous research that discusses the calculation method of lunar eclipses may be 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 specific and detailed research that discusses the calculation method of lunar eclipses in *Risālah az-Zain*.

Researches on Falak science that discussing the reckoning of lunar eclipses quite a lot. However, compared to this study, there are still differences that are pretty significant and fundamental. Several kinds of research are related to the calculation of lunar eclipses as follows**:**

Muhajir's article in *Jurnal Islam Nusantara* entitled "Hisab Gerhana Bulan dalam Kitab Nur Al-Anwar (Analisis Pemikiran KH. Noor Ahmad SS)[24] discusses lunar eclipse reckoning system in the book *Nūr al-Anwār* by KH. Noor Ahmad SS. This book uses Jepara for *Markāz* with coordinate 60º 36 'LS and 110º 40' LU. The reckoning system is essential *hisāb bi al-tahqīq* which is quite accurate and uses an ecliptic limit value of 120 and can be scientifically justified. The trigonometric formulas result from the modification and transformation of the formula form of the logarithmic formulas in the book of *Khulāṣah al-*

[24] Muhajir, "Hisab Gerhana Bulan Dalam Kitab Nur Al-Anwar (Analisis Pemikiran KH. Noor Ahmad SS)", *Jurnal UMSU: Jurnal Islam Nusantara,* vol. 3, no. 2, July-December 2019.

Wāfiyah, written by KH. Ahmad Zubair Umar al-Jaelany, into the trigonometry formulas.

Hasna Tuddar Putri's article in journal *Al-Marshad* entitled "Tinjauan Astronomi Terhadap Hisab Gerhana Bulan dalam Kitab *Ittifāq Zat al-Bain* Karya Moh. Zubair Abdul Karim".[25] This article discusses the lunar reckoning method in the book *Ittifāq Zat al-Bain*, which combines classical and modern algorithms. This algorithm is more straightforward than the lunar eclipse calculation algorithm in modern astronomy and lacks accuracy in terms of data. Nonetheless, this book scholars have enriched the treasury of eclipse reckoning.

'Alamul Yaqin's undergraduate thesis entitled *"Algoritme Hisab Gerhana Bulan Menurut Rinto Anugraha dalam Buku Mekanika Benda Langit".*[26] This research discusses the calculation of lunar eclipses in the book *Mekanika Benda Langit* (mechanics of celestial bodies) by Rinto Anugraha. This study measures the accuracy of these calculations by comparing them with the *Astronomical Algorithm, Canon of Lunar Eclipse 1500 B.C-A.D 300* and *NASA* calculations. Although both use contemporary calculations and are primarily sourced from the *Astronomical Algorithm*, this study is different because it has a different object of book research.

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[25] Hasna Tuddar Putri, "Tinjauan Astronomi Terhadap Hisab Gerhana Bulan dalam Kitab Ittifaq Zat al-Bain Karya Moh. Zubair Abdul Karim", *Jurnal UMSU: Al-Marshad*, vol. 6, no. 2, Desember 2020.

[26] Alamul Yaqin, *"*Algoritme Hisab Gerhana Bulan Menurut Rinto Anugraha dalam Buku Mekanika Benda Langit", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2017), not published.

Hanik Maridah's undergraduate thesis entitled "Studi Analisis Hisab Gerhana Bulan dalam Kitab *Maslak Al-Qāṣid Ilā 'Amal Ar-Rāṣid* Karya KH. Ahmad Ghozali Muhammad Fathullah".[27] It discusses books written by the same author of *Irsyād al-Murīd*, namely K.H. Ahmad Ghozali Muhammad Fathullah. Still, in contrast to the book *Irsyād al-Murīd,* it includes the tables as a characteristic of the steps of a classic book. This undergraduate thesis discusses the algorithm and accuracy in determining the timing of a lunar eclipse. This thesis is different from the thesis that the writer will analyze because the computation algorithm used in the form of a table is a feature of classical computation and the source of the book used by *Maslak al-Qāṣid Ilā' Amal Ar-Rāṣid*.

Wahyu Fitria's undergraduate thesis, an undergraduate at the Shari'a Faculty of IAIN Walisongo Semarang in 2015 entitled "Studi Komparatif Hisab Gerhana Bulan dalam Kitab Khulashah al-Wafiyyah and Ephemeris".[28] This research talks about the reckoning method in the book *Khulāṣah al-Wāfiyah* and comparison to the reckoning contemporary. The results remain under reckoning contemporary because the data generated by his contemporary is more valid and more accurate, and deep data

[27]Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan dalam Kitab *Maslak Al-Qāṣid Ilā 'Amal Ar-Rāṣid* Karya KH. Ahmad Ghozali Muhammad Fathullah", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2015), not published.

[28] Wahyu Fitria, "Studi Komparatif Hisab Gerhana Bulan dalam Kitab al-Khulashah al-Wafiyyah dan Ephemeris", *Undergraduate Thesis* IAIN Walisongo Semarang (Semarang, 2011), not published.

retrieval has used the same table already programmed on the computer.

Ahmad Ma'ruf Maghfur's undergraduate thesis entitled *Studi Analisis Hisab Gerhana Bulan dan Matahari dalam Kitab Fathu Rauf al- Manan*[29]. It contains the analysis of lunar eclipse reckoning method in the book *Fatḥ Raūf al-Mannan* written by Abdul Djalil Hamid Kudus.

Zaenudin Nurjaman's undergraduate thesis entitled "*Sistem Hisab Gerhana Bulan Analisis Pendapat KH. Noor Ahmad SS dalam Kitab Nūr al-Anwār"*[30]. It contains the analysis of lunar eclipse reckoning method in the book *Nūr al-Anwār* written by KH. Noor Ahmad.

Kitri Sulastri's undergraduate thesis entitled "*Studi Analisis Hisab Awal Bulan Kamariah dalam Kitab Al-Irsyād al-Murīd"*[31]. It contains the analysis of lunar eclipse reckoning method in the book *Al- Irsyād al-Murīd written by* Ahmad Ghazali Muhammad Fathullah.

Based on the above studies, the authors found no studies regarding the analysis of lunar eclipse reckoning method in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy. Several studies discuss the calculation of lunar

[29] Ahmad Ma'ruf Maghfur, "Studi Analisis Hisab Gerhana Bulan dan Matahari dalam kitab Fathu Rauf al- Manan". *Undergraduate Thesis* IAIN Walisongo Semarang (Semarang, 2012), not published.

[30] Zaenudin Nurjaman, "Sistem Hisab Gerhana Bulan Analisis Pendapat KH. Noor Ahmad SS dalam Kitab Nūr al-Anwār" Undergraduate Thesis IAIN Walisongo Semarang (Semarang: 2012), not published.

[31] Kitri Sulastri, "Studi Analisis Hisab Awal Bulan Kamariah dalam Kitab Al- Irsyād al-Murīd". *Undergraduate Thesis* IAIN Walisongo Semarang (Semarang, 2011), not published.

eclipse, but not leading to the reckoning of the eclipse contained within the book *Risālah az-Zain*

F. Research Methodology

The methodology is the researcher's guidance to discover the purpose of this research. Cambridge dictionary defines methodology as *"a system of ways of doing, teaching, or studying something"*. Methodology is the researcher's guidance to discover the purpose of this research. In this research, the writer uses the following research methods:

1. Type of Research

This research is included in library research. Its research conducted using literature and written data sources in carrying out library analysis.[32] This type of research is qualitative[33], with a descriptive approach that aims to address existing problem solutions based on data to be analyzed and interpreted. [34]

In this research, the writer will describe the method of calculating the lunar eclipse of The Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy. This research is aimed to produce an in-depth description of the

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[32] M. Iqbal Hasan, *Pokok–Pokok Metodologi Penelitian dan Aplikasinya*, (Bogor: Ghalia Indonesia, 2002), 11.

[33] Qualitative analysis basically places more emphasis on deductive and inductive processes and on the analysis of the dynamics between observed phenomena, using scientific logic. See Saifuddin Azwar, *Metode Penelitian*, (Yogyakarta: Pustaka Pelajar, 2004), cet.5, 5.

[34] Narbuka, Cholid and Abu Achmadi, *Metodologi Penelitian*, (Jakarta: Bumi Aksara, 2008), 65.

characteristics of the object under study so that it can be tested whether the method is following scientific truth and can be used as a reference in calculating the lunar eclipse.

2. Resource

According to the source, the research data is classified into primary and secondary data.[35]

a. Primary Resource[36]

Primary data or first-hand data is data obtained directly from the research object. Primary data of this study are data obtained from the lunar eclipse calculation method in the Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy.

b. Secondary Resource

Secondary data is not directly obtained by the researcher from the object of research and is usually arranged in documents. [37] To clarify this research, the writer will conduct interviews and direct discussions with Ibn Ya'qūb al-Batāwy as the author of the *Risālah az-Zain*. Besides that, the author also obtains secondary data from documentation in writings about eclipses, encyclopedias, dictionaries, articles, books, and journals.

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[35] Saifuddin Azwar, *Metode,* 91.

[36]Primary data is first-hand data or data obtained or collected directly in the field by the person conducting the research or those concerned who need it. Look M. Iqbal Hasan, Pokok, 82.

[37] Saifuddin Azwar, *Metode,* 91.

3. Method of Collecting Data

To obtain the data needed in this research, the writer uses two data collection methods, as follow:

a. Documentation

This method is used to collect data and examine things or variables in the form of documents relevant to the research study. It aims to obtain primary data related to the lunar eclipse. The author also reviews and analyzes the data sources, such as scientific journals, books, articles related to the calculation of lunar eclipses, and other sources relating to the problems to be studied.

b. Interview[38]

This interview is conducted to gather a lot of information from the informant or the person being interviewed.[39] The type of interview used is a structured interview, which is an interview in which the questions are compiled before being asked to the informant.

The informants interviewed were from the author of the book *Risālah az-Zain* himself. This interview aimed to know a brief biography Ibn

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[38]Interview is a form of communication between two people, involving someone who wants to get information from another person by asking questions based on specific objectives. See Deddy Mulyana, *Metode Penelitian Kualitatif Paradigma Baru Ilmu Komunikasi dan Ilmu Sosial Lainnya,* (Bandung: Remaja Rosdakarya, 2004), cet. 4, 180.

[39]Andi Prastowo, *Metode Penelitian Kualitatif, Dalam Prespektif Rancangan Penelitian,* (Yogyakarta: ar-Ruzz Media, 2012), 212.

Ya'qūb al-Batāwy, and understand the systematic calculation of lunar eclipses he wrote. Interviews were also conducted with several competent experts in the fields of astronomy and astronomy.

Due to this research was carried out during the COVID-19 pandemic which requires every community to prevent the spread of the coronavirus, government obligate the public to carry out physical distancing and reduce physical contact between humans which forces the interviews has to be conducted online via chat application: WhatsApp.[40]

4. Data Analysis Technique

After the required data is collected from documentation and interviews, the author will analyze the data. Data analysis is a method that uses procedures to conclude a book or document.[41] It aims to describe the method of calculation of the lunar eclipse in the *Risālah az-Zain.* After the required data is collected, the writer uses the *descriptive analysis method*.[42]

[40] WhatsApp is free and multiplatform messaging apps that user can sending and receiving a variety of media: text, photos, videos, document, location, and voice calls.

[41] Djam'an Satori, *Metodologi Penelitian Kualitatif*, (Bandung: Alfabeta, 2009), 157.

[42] Descriptive research is research conducted to determine the value of independent variables, either one or more variables without making comparisons or relating them to other variables. See Beni Kurniawan, *Metodologi Penelitian*, (Tangerang: Jelajah Nusa, 2012), 20.

The descriptive analysis describes the properties or circumstances that are used as objects in a study. This description method is used to explain the truth and error of an analysis developed in a balanced way by looking at the advantages and disadvantages of the object under study.[43]

The analysis process begins with collecting references related to the lunar eclipse reckoning to produce new data. The author did describe the thoughts of Ibn Ya'qūb al-Batāwy in calculating a lunar eclipse. Then the author describes and explores the method of using a lunar eclipse. The author analyzes the accuracy of the lunar eclipse calculation to find out the accuracy of the results of the lunar eclipse reckoning from the book and can assess the advantages and disadvantages.

G. Systematic of Writing

To achieve the purpose of this research, the writer organized this thesis by the system of writing with five chapters based on the second model of the 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 the chapter (1) in term to get efficiency and effectiveness in the thesis writing.[44]. for more details, the contents are as follows:

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[43] M. Iqbal Hasan, *Pokok*, 136.

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

The first chapter contains the background of the research, the formulation of the problem to be studied, the objectives and benefits of the research. Literature review and research methods that explain the technical analysis will be carried out in the research and framework of writing the thesis.

The second chapter discusses eclipses in general, including basic theories about lunar eclipses, the fundamental law of lunar eclipses, lunar eclipse objects, lunar eclipse history, types of lunar eclipses, lunar eclipse geometry, eclipse cycles, and calculation classifications of the lunar eclipse.

The third chapter describes the intellectual biography of Ibn Ya'qūb al-Batāwy, the general description of the book *Risālah az-Zain* and the method of calculation the lunar eclipse in the book *Risālah az-Zain.*

The fourth chapter, the main points of this thesis, analyze the method of calculation the lunar eclipse in the book *Risālah az-Zain* and the accuracy of the lunar eclipse reckoning method used by Ibn Ya'qūb al-Batāwy in the book *Risālah az-Zain.*

The fifth chapter contains conclusions and suggestions related to the discussion and research results that the author adopts about calculating the lunar eclipse in the book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy and then the closing line.

CHAPTER II

GENERAL REVIEW OF LUNAR ECLIPSE

A. Understanding Lunar Eclipse

Early Greeks define eclipses as shadow effects. (Tarbuck and Lutgcns, 1976).[1] The word eclipse (Greek: *έκλειψη*) is strictly a medical term, meaning a faint or swoon. Astronomically it is applied to the darkening of a heavenly body, especially of the Sun or the Moon. However, some of the satellites of other planets besides the Earth are also "eclipsed" from time to time. Its passage causes an eclipse of the Moon through the shadow of the Earth; an eclipse of the Sun, by the interposition of the Moon between the Sun and the observer, or, what comes to the same thing, by the passage of the Moon's shadow over the observer.[2]

Eclipse is an occasion when the Moon passes between the Earth and the Sun so that you cannot see all or part of the Sun for a time; an occasion when the Earth passes between the Moon and the Sun so that you cannot see all or part of the Moon for a time.[3] Eclipses of the Moon occur when the

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[1] Emmanual Adinna, *Understanding the Eclipse,* (SNAAP Press Ltd, 2006), 2.

[2] Charles a Young, *A Text Book of General Astronomy for Collages and Scientific Schools,* (Boston and London: Ginn & Company, Publisher, 1889), 233.

[3]Oxford, "Oxford Advanced Learner's Dictionary", https://www.oxfordlearnersdictionaries.com/, accessed on 15 January 2021.

Moon, at full phase, passes through the Earth's shadow and is therefore darkened.[4]

The axis of the Earth's shadow is always directed to a point exactly opposite the Sun. If then, at the time of the full moon, the Moon happens to be near the ecliptic (that is, not far from one of the nodes of her orbit), she will pass into the shadow and be eclipsed. Since, however, the Moon's orbit is inclined about five and one-fourth degrees to the plane of the ecliptic, this does not happen very often (seldom more than twice a year). Ordinarily, the Moon passes north or south of the shadow without touching it.[5]

Astronomers consider eclipses as an outcome of the natural interaction of the major components of the "earth system" viz the Sun, the Earth, and the Moon. Some traditional adherents to the unknown consider eclipses as visitations from gods in reaction to inconsistent human behaviors. Consequent to these definitions, eclipse events have led to mixed effects of fears, suspicion, superstition, inquiries, surprises, enjoyment, economic benefits, and losses and in extreme cases, they constitute health hazards to humans.[6]

Many ancient civilizations used to think that a lunar eclipse was disastrous and some others believed that it was a blessing, here are the myths related to a lunar eclipse: [7]

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[4] Robert H. Baker, *Astronomy*, 140.

[5] Charles a Young, *A Text Book of General Astronomy*, 235.

[6] Emmanual Adinna, *Understanding*, 2.

[7] Daniel Brown, "Blood Moon: Lunar Eclipse Myths from Around The World", https://theconversation.com/blood-moon-lunar-eclipse-myths-from-around-the-world-100548, accessed on 21 January 2021.

1. The ancient Inca people interpreted the deep red coloring as a jaguar attacking and eating the Moon. They believed that the jaguar might then turn its attention to Earth, so the people would shout, shake their spears and make their dogs bark and howl, hoping to make enough noise to drive the jaguar away.
2. In ancient Mesopotamia, a lunar eclipse was considered a direct assault on the king. Given their ability to predict an eclipse with reasonable accuracy, they would put in place a proxy king for its duration. Someone considered to be expendable (it was not a popular job), would pose as the monarch, while the real king would go into hiding and wait for the eclipse to pass. The proxy king would then conveniently disappear, and the old king is reinstated.
3. Some Hindu folktales interpret lunar eclipses as the result of the demon Rahu drinking the elixir of immortality. Twin deities, the Sun and the Moon, promptly decapitate Rahu, but Rahu’s head remains immortal after consuming the elixir. Seeking revenge, Rahu’s head chases the Sun and the Moon to devour them. If he catches them, we have an eclipse – Rahu swallows the Moon, which reappears from his severed neck.
4. For many people in India, a lunar eclipse bears ill fortune. Food and water are covered and cleansing rituals are performed. Pregnant women especially should not eat or carry out household work to protect their unborn child.

5. The Native American Hupa and Luiseño tribes from California believed that the Moon was wounded or ill. After the eclipse, the Moon would need healing, either by the Moon's wives or tribe members. The Luiseño, for example, would sing and chant healing songs towards the darkened Moon.
6. Altogether more uplifting is the legend of the Batammaliba people in Togo and Benin in Africa. Traditionally, they view a lunar eclipse as a conflict between Sun and Moon, which the people must encourage them to resolve. Therefore, it is a time for old feuds to be laid to rest, a practice that has remained until this day.
7. In Islamic cultures, eclipses tend to be interpreted without superstition. In Islam, the Sun and Moon represent deep respect for Allah, so during an eclipse special prayers are chanted including a *Ṣalāt al-khusūf*, a "prayer on a lunar eclipse". It both asks Allah's forgiveness and reaffirms Allah's greatness.

Eclipse in Arabic is known as *kusūf* and *khusūf.* The terms *kusūf* and *khusūf* are used to refer to solar and lunar eclipses. The word *kusūf* is better known for expressing a solar eclipse, while the word *khusūf* is for a lunar eclipse.[8] According to etymology (language), *kusūf* means to assume a stern look, to be frowned (face) as said *'kāsif al-wajhi aw al-bāli'* (Stern-faced. Frowning).[9] It is said to be *kasafat ash-shams*, i.e., the Sun turns black (dark) and its light

[8] Muhyiddin Khazin, *Kamus*, 45.
[9] Hava J., *Arabic-English Dictionary* (Beyrut: Catholic Press, 1899), 647.

disappears. Some say that *khusūf* is losing its light, while *kusūf* when its light changes.[10]

Kusūf means "to cover". The word illustrates the natural phenomenon that (seen from Earth) the Moon covers the Sun, resulting in a solar eclipse. While *khusūf* means "to enter," describing the Moon's natural phenomenon enters the Earth's shadow, resulting in a lunar eclipse.[11]

Khasafa means "lost, vanished, or drowned". This particular word has a verse which is a series of verses that describe the atmosphere of the doomsday. Because of that, the word typically means that the Moon disappears or the Moon itself disappears because the end of the world means the destruction of all creation, of course, including the Moon.[12]

In terms of language, they both mean eclipses, but *kusūf* is better known for mentioning solar eclipses *(kusūf ash-Shams)* and *khusūf* is known for mentioning lunar eclipses *(khusūf al-Qamar)*. The term Eclipse is generally used in the designation of an eclipse, both a solar eclipse and a lunar eclipse.[13]

According to the term, a lunar eclipse is the occurrence of something that happens to the Moon. The Moon is in the middle of the Earth's shadow, so sunlight cannot reach the Moon. Meanwhile, a solar eclipse is

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[10] Imam An-Nawawi, *Syarah Shahih Muslim*, fourth edition (Jakarta: Darus Sunnah Press, 2014), Third Edition, 789.

[11] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktik*, 187.

[12] Agus Purwanto, *Ayat-Ayat Semesta Sisi-Sisi Yang Terlupakan*, (Bandung: Mizan Media Utama, 2008), cet II, 257.

[13] Ahmad Izzuddin, *Ilmu Falak Praktis*, 105.

blocking sunlight from the Sun due to the Moon blocking the Sun.[14]

From the various meanings above, we can understand the true meaning of a lunar eclipse. From the opinion of experts, either in terms of etymology, the mention of a solar eclipse and a lunar eclipse have different names, namely *kusūf* and *khusūf*.

In essence, both of them can be used for designation, either a solar eclipse or a lunar eclipse. It's just that, the word *kusūf* is better known for the mention of solar eclipses *(kusūf ash-Shams)* and the word *khusūf* is better known for the mention of a lunar eclipse *(khusūf al-Qamar)*.[15]

B. The Islamic Law of Lunar Eclipse

High precision Sun and Moon ephemeris data is needed for calculation in astronomy and aims to determine the occurrence of an eclipse of the Sun and Moon with the Muslims' intention to perform lunar eclipse prayers *(khusūf al-shams)* or solar eclipse prayers *(kusūf al-shams*).[16] In Holy Qur'an, several verses are explained used as the basis for determining an eclipse, as follows:

1. Surah Ya-Sin: 38-40

[14] Zubair Umar al-Jaelany, *al-Khulasah al-Wafiyyah*, (Kudus: Menara Kudus, 1955), 149.

[15] Sub Direktorat Pembinaan Syariah dan Hisab Rukyat Direktorat Urusan Agama Islam dan Pembinaan Syariah Direktorat Jederal Bimbingan Masyarakat Islam Kementerian Agama Republik Indonesia, *Ilmu Falak Praktik*, (Jakarta: Direktorat Peradilan Agama, 2013), 109.

[16] M. Basthoni, "Accuracy of Solar Eclipse Calculation Algorithm Based on Jet Propulsion Laboratory Data Nasa", *Al-Ahkam*, vol. 30, no. 1, 2020, 96.

وَٱلشَّمۡسُ تَجۡرِي لِمُسۡتَقَرّٖ لَّهَاۚ ذَٰلِكَ تَقۡدِيرُ ٱلۡعَزِيزِ ٱلۡعَلِيمِ
(٣٨) وَٱلۡقَمَرَ قَدَّرۡنَٰهُ مَنَازِلَ حَتَّىٰ عَادَ كَٱلۡعُرۡجُونِ ٱلۡقَدِيمِ
(٣٩) لَا ٱلشَّمۡسُ يَنۢبَغِي لَهَآ أَن تُدۡرِكَ ٱلۡقَمَرَ وَلَا ٱلَّيۡلُ سَابِقُ
ٱلنَّهَارِۚ وَكُلّٞ فِي فَلَكٖ يَسۡبَحُونَ (٤٠)

"And the Sun runs his course for a period determined for him: that is the decree of (Him) the exalted in Might the All-Knowing (38). And the Moon We have measured for her mansions (to traverse) till she returns like the old (and withered) lower part of date-stalk (39). It is not permitted to the Sun to catch up the Moon nor can the Night outstrip the Day: each (just) swims along in (its own) orbit (according to Law) (40)."[17]

Abdullah Yusuf Ali[18] gives a commentary on these verses:

In verse 38, place 36. I think the first meaning is best applicable here, but some Commentators take the second meaning. In that case, the simile would be that of the Sun running a race while he is visible to us and taking a rest during the night to prepare himself to renew his race the following day. His stay with the antipodes appears to us as his period of rest.[19]

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[17] Abdullah Yusuf Ali, *The Holy Quran English Translation of the Meaning and Commentary,* (Medina, Saudi Arabia: King Fahd Printing Complex, 1991), 1326.

[18] Abdullah Yusuf Ali (1872-1953) is the author of the most popular Holy Quran translation in the English language. Born on 4 April 1872 in Surat, Gujarat, India. Look *Oxford Dictionary of National Biography*.

[19] Abdullah Yusuf Ali, *The Holy Quran,* 1326.

In verse 38, Allah explains the evidence of His power, namely the circulation of the Sun, which moves on a certain path in an orderly manner according to the provisions set by Allah. He did not deviate in the slightest from that predetermined line. If he strayed from the tip of his hair, there would be a collision with other heavenly objects. We cannot imagine what will happen as a result of that event. It turns out that what is determined by astronomy is in line with what has been explained in verse. Therefore, it is not an exaggeration to say that the higher the ability of human science and technology, the more open the truths that have been presented in the Qur'an since fourteen centuries ago.[20]

Whereas in verse 39, Allah has determined certain distances for the Moon's orbit so these distances may changes: in shape, size, and strength of its rays. At first, the Moon appeared in small and weak light, and then he became a crescent moon with a curved shape and a brighter light. Furthermore, the shape becomes more perfectly round to become a Full Moon with a very bright light. But then it shrinks further so that at last it resembles a dry bunch curved with fading light, returning to its original state.[21]

In verse 40, it is explained that based on the arrangements and decrees of Allah that apply to natural

[20] Direktorat Jenderal Bimbingan Masyarakat Islam Direktorat Urusan Agama Islam dan Pembinaan Syari'ah, *Al-Qur'an dan Tafsirnya*, eighth edition, (Jakarta: PT. Sinergi Pustaka Indonesia, 2012), 226.

[21] Ibid.

objects, the rule called *sunnatullāh*[22], it is not possible for a collision between the Sun and the Moon and neither night precedes day. Everything will go according to the rules that he has established. Each one remains in motion according to the path that Allah has established for him.[23]

It does not behoove — it is [neither] facilitated nor is it right for — the Sun to catch up with the Moon and so appear together with it at night nor may the night outrun the day and thus it [the night] never arrives before the latter ends and each (kullun: the nunation compensates for the [missing] genitive annexation [that would have been constructed] with *ash-Shams* 'the Sun' *al-Qamar* 'the Moon' and al-nujūm 'the stars' [of these] is in an orbit, swimming, moving, — these [celestial bodies] are being treated as [though they were] rational beings.[24]

2. Surah Al-An'am: 96

فَالِقُ ٱلۡإِصۡبَاحِ وَجَعَلَ ٱلَّيۡلَ سَكَنٗا وَٱلشَّمۡسَ وَٱلۡقَمَرَ حُسۡبَانٗاۚ ذَٰلِكَ تَقۡدِيرُ ٱلۡعَزِيزِ ٱلۡعَلِيمِ (٩٦)

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[22] Sunnah literally means pathway, tradition, way, method and custom. It also stands for consistency and order. Therefore, *sunatullah* means God has a behavior which is permanent and also special to him, or we can say it is "God's costumary way of acting". Look Esra Mikail, "Sunnatullah", https://prezi.com/f9mleftsyv6e/sunnatullah, accessed on 20 January 2021.

[23] Direktorat Jenderal Bimbingan Masyarakat Islam Direktorat Urusan Agama Islam dan Pembinaan Syari'ah, *Al-Qur'an*, 227.

[24] Jalaluddin al-Mahalli and Jalaluddin as-Suyuthi, *Tafsir al-Jalalayn*, trans. by Feras Hamza (Jordan: Royal Aal al-Bayt Institute for Islamic Thought, 2007), 505.

"He it is that cleaveth the daybreak (from the dark): He makes the night for rest and tranquillity and the Sun and Moon for the reckoning (of time): such is the judgment and ordering of (Him) the Exalted in Power the Omniscient."[25]

This verse describes that Allah is the Cleaver of the daybreak (al-isbāh is the verbal noun meaning *aṣ-ṣubh* 'dawn'), in other words, He splits the morning shaft the first light that appears after the darkness of night, and He has appointed the night for stillness, in which creatures rest from toil, and the Sun and the Moon (read both in the accusative *wa ash-shamsa wa al-qamara* as a supplement to the [syntactical] status of *al-layla* 'the night') for reckoning, for the calculation of [periods of] time or [if the prefixed preposition] *bā'* is [considered to have been] omitted [*bi-husbān*], making it [*husbān*] a circumstantial qualifier referring to an implied verb [such as *yajriyān* 'they follow courses'], that is 'they follow courses precisely calculated [*bi-husbān*]', as is stated in the verse of [sūrat] al-Rahmān [Q. 55:5]). That, mentioned, is the ordaining of the Mighty, in His kingdom, the Knowing, of His creation.[26]

The word حُسْبَانًا itself is a word taken from the word حِسَاب or reckoning. The addition of the alif and nun letters to the word means perfection. So that the

[25] Abdullah Yusuf Ali, *The Holy Quran,* 369.
[26] Jalaluddin al-Mahalli and Jalaluddin as-Suyuthi, *Tafsir al-Jalalayn,* 146.

word حُسْبَانًا means perfect and accurate calculation, the consistent and accurate circulation of celestial bodies will not result in collisions between planets. With this consistent circulation, it can be calculated so that it can be seen when the eclipse occurs.[27]

3. Surah Al-Qiyamat: 8

وَخَسَفَ ٱلۡقَمَرُ (٨)

"And the Moon is buried in darkness.[28]

Khasafa means lost, disappeared, and drowned. This verse is a series of the previous verses describing the atmosphere of the end. Therefore, the word peculiar can only stop the light of the Moon or the Moon itself which disappears because of the apocalypse.[29]

The mention of this verse contains two possibilities. First, it meant that the *khusūf* was only used for lunar eclipses as stated in the Al-Qur'an. If *khusūf* is only used for lunar eclipses, it means that *kusūf* is specifically used for solar eclipses. Second, it means that what applies to the Sun also applies to the Moon. While the lunar eclipse in the Qur'an is expressed in the word *khusūf*, then this word can also be used for the Sun.[30]

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[27] M. Quraish Shihab, *Tafsir al-Misbah, Pesan, Kesan dan Keserasian al-Qur'an,* fifth edition, (Jakarta: Lentera Hati, 2015) vol. 11, 569.

[28] Abdullah Yusuf Ali, *The Holy Quran,* 1857.

[29] Agus Purwanto, *Ayat-Ayat Semesta,* 257.

[30] Al Imam al Hafiz Ibnu Hajar al-Asqalani, *Fathul Bari,* sixth edition, (Jakarta: Pustaka Azzam, 2011), 33.

It can be concluded that in Arabic. The meaning of the words *Khusūf* and *Kusūf* are not the same. But in terms of being used to describe a solar eclipse, a lunar eclipse, or both, the scholars still have different opinions. According to the term, a lunar eclipse is the occurrence of something that happens to the Moon, namely the Moon is in the middle of the Earth's shadow so that the Sun's rays cannot reach the Moon.[31] Meanwhile, a solar eclipse is the blocking of sunlight from the Sun, due to the Moon blocking the Sun.[32]

4. Surah Fussilat: 37

وَمِنْ ءَايَٰتِهِ ٱلَّيْلُ وَٱلنَّهَارُ وَٱلشَّمْسُ وَٱلْقَمَرُ لَا تَسْجُدُوا۟ لِلشَّمْسِ وَلَا لِلْقَمَرِ وَٱسْجُدُوا۟ لِلَّهِ ٱلَّذِى خَلَقَهُنَّ إِن كُنتُمْ إِيَّاهُ تَعْبُدُونَ (٣٧)

"Among His Signs are the Night and the Day and the Sun and Moon. Adore not the Sun and the Moon but adore Allah Who created them if it is Him ye wish to serve."[33]

This verse describes the greatness of Allah through its creation: day and night, Sun and Moon. Abdullah Yusuf Ali commented that Night and Day are opposites, and yet, by the alchemy of Allah, they can both subserve the purpose of human good, because the Night can give rest while the Day can promote activity.

[31] Zubair Umar al-Jaelany, *al-Khulasah al-Wafiyyah*, 139.
[32] Zubair Umar al-Jaelany, *al-Khulasah al-Wafiyyah*, 149.
[33] Abdullah Yusuf Ali, *The Holy Quran,* 1465.

The Sun and the Moon are similarly complimentary. So, in moral and spiritual affairs, seeming opposites may by Allah's alchemy be made to subserve the purposes of Good. They are but instruments: Allah is the Cause. Adore Allah and not the things which He has created. Use the things which He has created, but do not adore them.[34]

Allah forbids the worship of the Moon and Sun in any form. Because even though both of them are great creations of Allah but the virtues they have do not come from both of them so that they have the same right as Allah to be worshiped. There is still Allah who created both of them. If Allah wishes He can nullify both or remove the light of both. [35]

5. Hadist Narrated Abu Bakar

حَدَّثَنَا عَمْرُو بْنُ عَوْنٍ، قَالَ حَدَّثَنَا خَالِدٌ، عَنْ يُونُسَ، عَنِ الْحَسَنِ، عَنْ أَبِي بَكْرَةَ، قَالَ كُنَّا عِنْدَ رَسُولِ اللَّهِ صلى الله عليه وسلم فَانْكَسَفَتِ الشَّمْسُ، فَقَامَ النَّبِيُّ صلى الله عليه وسلم يَجُرُّ رِدَاءَهُ حَتَّى دَخَلَ الْمَسْجِدَ، فَدَخَلْنَا فَصَلَّى بِنَا رَكْعَتَيْنِ، حَتَّى انْجَلَتِ الشَّمْسُ فَقَالَ صلى الله عليه وسلم " إِنَّ الشَّمْسَ

[34] *Ibid.*

[35] Syaikh Imam al-Qurtubi, *al Jami' Lil Ahkam Al-Qur'an,* (Jakarta: Pustaka Azzam, 2009), 888.

وَالْقَمَرَ لاَ يَنْكَسِفَانِ لِمَوْتِ أَحَدٍ، فَإِذَا رَأَيْتُمُوهُمَا فَصَلُّوا، وَادْعُوا، حَتَّى يُكْشَفَ مَا بِكُمْ ". [36]

"Telling us Amr ibn 'Aun said: telling us Khalid from Yunus from Hasan from Abi Bakrah said: "We were with Allah's Messenger (ﷺ) when the Sun eclipsed. Allah's Messenger (ﷺ) stood up dragging his cloak till he entered the Mosque. He led us in a two-rak'at prayer till the sun (eclipse) had cleared. Then the Prophet (p.b.u.h) said, "The Sun and the Moon do not eclipse because of someone's death. So whenever you see these eclipses pray and invoke (Allah) till the eclipse is over."

The hadith above provides information related to the timing of the eclipse prayer. The hadith shows that the prayer time for an eclipse starts when the eclipse occurs until conditions become clear again. Syekh al-Islam Ibn Taimiyyah revealed that the timing of an eclipse sometimes takes a long time and sometimes only occurs in a short time according to the part of the Sun that is affected by the eclipse.[37]

When the weather has returned to bright while someone is still praying, let him finish by fastening his prayer. If the Sun and Moon are covered by clouds

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[36] Imam Abi Abdillah Muhammad ibnu Ismail ibnu Ibrahim ibnu al-Mughirah ibnu Bardazbah al-Bukhari al-Ja''fiy, *Shahih Bukhari*, Juz Awal, (Beirut: Daruul Kitab al-Alamiah, 1992), 216.

[37] Saleh bin Fauzan, *Fiqh Sehari-hari*, translated from *Al-Mulakhkhasul Fiqhi* by Abdul Hayyie al Kattani et.al., (Jakarta: Gema Insani, 2005), 215.

when they are experiencing an eclipse, a person will still pray because the law of origin of the eclipse happened.[38]

6. Hadith Narrated Ibn' Umar

حَدَّثَنَا أَصْبَغُ، قَالَ أَخْبَرَنِي ابْنُ وَهْبٍ، قَالَ أَخْبَرَنِي عَمْرٌو، عَنْ عَبْدِ الرَّحْمَنِ بْنِ الْقَاسِمِ، حَدَّثَهُ عَنْ أَبِيهِ، عَنِ ابْنِ عُمَرَ ـ رضى الله عنهما ـ أَنَّهُ كَانَ يُخْبِرُ عَنِ النَّبِيِّ صلى الله عليه وسلم. إِنَّ الشَّمْسَ وَالْقَمَرَ لاَ يَخْسِفَانِ لِمَوْتِ أَحَدٍ وَلاَ لِحَيَاتِهِ، وَلَكِنَّهُمَا آيَتَانِ مِنْ آيَاتِ اللَّهِ، فَإِذَا رَأَيْتُمُوهَا فَصَلُّوا[39]

"Asbagh has told us that he said: Ibn Wahb has told a story to me, he said: had told me 'Amr from Abdur Rahman bin Qasim that he had told him from his father. From Ibn Umar r.a, that Umar got news from the Prophet (ﷺ) said, "The Sun and the Moon do not eclipse because of the death or life (i.e., birth) of someone but they are two signs amongst the signs of Allah. When you see them offer the prayer."

From the hadith, it can be understood that the occurrence of a lunar eclipse is not an event that causes a disaster, someone's death, or someone's birth, and so on. An eclipse is one of the signs of the greatness of Allah which, if Muslims see it is advisable to pray as

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[38] Sa'id bin 'Ali bin Wahf al-Qahthani, *Shalatul Mu'min,* translated form *Ensiklopedi Shalat Menurut al-Qur'an dan as-Sunnah* by Ahmad Yunus and Fatkhurahman, third edition, (Jakarta: Pustaka Imam asy-Syafi'I, 2007), 41.

[39] Ibid., 14.

much circumcision and remembrance as possible to Allah.[40] The clerics agree that *salat kusūf* is the *sunnah mu'akkad*[41], both for men and women.[42]

Likewise, according to astronomy, an eclipse is simply an event of blocking the Sun's rays from reaching the Earth's surface (during a solar eclipse), or Earth's blocking of sunlight from reaching the Moon's surface at a full moon (lunar eclipse). All of this is simply the greatness and will of Allah.[43]

Furthermore, astronomy can calculate when an eclipse occurs and applies to any area, long before the eclipse itself occurs so that Muslims can be prepared to wait for the eclipse to arrive and prove it. Muslims can prepare earlier to hold eclipse prayer and sermons.[44]

C. Object of Lunar Eclipse Study

1. Moon

The Moon is our nearest neighbor in the celestial spaces and the only satellite of the Earth and accompanies us in our annual motion around the Sun.[45] The distance of the Moon from planet Earth is about 384,446 kilometers. Conditions on this planet are cold

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[40] Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan" 22.

[41] *Sunnah mu'akkadah* refers to any voluntary act of worship which the Prophet Muhammad continuously performed and almost never abandoned. These are not obligatory, but a person who abandons them is considered blameworthy.

[42] Sayyid Sabiq, *Fiqh Sunnah*, first edition, (Jakarta: Pena Pundi Aksara, 2006), 308.

[43] Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan", 23.

[44] Ibid.

[45] Charles a Young, *A Text Book of General Astronomy*, 149.

and dry, the lowest temperature can reach 177 degrees below zero and the hot temperature when the Sun's light is shining in parts of it can reach 184 degrees above zero. Because of this extreme difference in air temperature, this planet is physically uninhabited by living things.[46]

The Moon is the only satellite on Earth with a diameter of 3,476 km, with a circumference of the Moon reaching 3,500 km. Once rotate the Earth, the Moon takes what is called the sidereal period 27d 7h 43m 11s (orbital period). The periodic variations in the Earth-Moon-Sun system are responsible for the occurrence of Moon phases recur every 29d 12h 44m 3s (period synodic).[47]

The Moon's density (3.4 g / cm3) is lighter than Earth's density (5.5 g / cm3), while the Moon's mass is only 0.012 Earth masses. The Moon that is pulled by Earth's gravitational force does not fall on Earth because it is pulled by the centrifugal[48] force arising from the Moon's orbit around the Earth.[49] The distance from the Moon and the Sun is 149,615,600 km, while Moon's perigee[50] (حضيض) is the 363,300 km, and

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[46]Slamet Hambali, *Pengantar Ilmu Falak: Menyimak Proses Pembentukan Alam Semesta*, (Banyuwangi: Bismillah Publisher, 2012), 133-134.

[47] Slamet Hambali, *Pengantar Ilmu Falak*,135.

[48] Centrifugal force is an outward force apparent in a rotating reference frame. Look John Robert Taylor, *Classical Mechanic*, (Sausalito CA: University Science Books), chapter 9, 344.

[49] Slamet Hambali, *Pengantar Ilmu Falak*, 136.

[50] Perigee is the point in its orbit where an Earth satellite closest to Earth.

Moon's apogee[51] (أ ج) 405,500 km, while the age of the Moon is 4,420,000,000 years.

The magnitude of the Moon's centrifugal force is slightly greater than the attractive force between Earth's gravitational forces and the Moon. This causes the Moon to move further away from Earth at a speed of about 3.8 cm/year. The Moon is in an orbit synchronous with Earth, which means that only one surface of the Moon can be observed from Earth. Synchronous orbit causes the rotation time to be the same as the rotation time.[52]

There is neither air nor water on the Moon. Impacts of comets or asteroids have caused many of the craters that have been produced on the surface of the Moon. The absence of air and water on the Moon causes no erosion, which results in many craters on the Moon that are millions of years old and still intact. Among the largest craters is Clavius with a diameter of 230 km and a depth of 3.6 km. The absence of air also causes no sound on the Moon.[53]

The Moon is the only celestial body that humans have ever visited and landed on. The first artificial object that passed near the Moon was the Soviet Union's spacecraft, Luna 1, the first object to hit the surface of the Moon was Luna 2, and the first photo of

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[51] Apogee is the point in its orbit where an Earth satellite is farthest from Earth.

[52] Slamet Hambali, *Pengantar Ilmu Falak,* 136.

[53] *Ibid.*

the far side of the Moon that was never seen from Earth, was taken by Luna 3, all missions were carried out. in 1959 AD the first spacecraft to successfully make landfall was Luna 9, and the one that successfully orbited the Moon was Luna 10, both carried out in 1966 AD, the United States' Apollo 11 program is the only manned mission to date that has made six landings. manned between 1969 AD and 1972 AD.[54]

2. Earth

Earth is a derivative of the old English and German names. However, there are hundreds of other names for Earth in various languages. In Roman mythology, the Earth was known as Tellus (fertile land). The Greeks called it *Gaia, Terra Mater*, or Mother Earth.[55]

In the Solar System, only the Earth is suited for advanced life of our kind" it lies in the middle of the "ecosphere", the region around the Sun where temperatures are neither too high nor too low.[56] The distance from the Earth to the Sun is 150,000,000 kilometers away. As a result of the elliptical shape of its orbit around the Sun, this distance is not constant at all places and angles. There is a range of 34000 kilometers. It has a diameter of 12,742km at the equator. [57]

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[54] *Ibid.*

[55] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktik*, 131.

[56] Patrick Moore, *The Data Book of Astronomy*, (London: Institute of Physics Publishing, 2000), 98.

[57] Emmanual Adinna, *Understanding*, 4.

The Earth revolves around the Sun on an elliptical orbit once in 365 1/4 days. It rotates on its axis once in 23hrs 56mins 4seconds - giving rise to periods of sunlight (day) and darkness (night). As the Earth rotates on its axis, it is inclined at an angle of 231/20 from the vertical and 661/2° from the horizontal. This makes it possible for sun-light to an incident at 90° on different latitudes between 231/20 North and 231/20 South of the central parallel - the equator. This inclination and the elliptical orbit helps to explain why eclipses do not occur at a place at constant intervals. The rotation also flattens the Earth at the poles, thus reducing the polar diameter by 40km less than the equatorial diameter. It also increases the curvature of the Earth's surface from 40° North and South to the poles. The curvature of the Earth's surface influences the latitudinal distance of the eclipse and the total area covered.[58]

Earth has a very friendly atmosphere for living things because the distance is not too close but also not too far from the Sun. The tilt of the Earth's axis of rotation towards the ecliptic plane has prevented overheating below the Earth's equator. Without this tilt, the temperature difference between the equatorial region and the poles will be very extreme and it is difficult for the life of creatures (humans, animals, and plants) to exist. Earth's magnetic field is also very friendly, unlike

[58] *Ibid.*

the other eight planets in our solar system. Allah has created the Earth with an atmosphere that not only protects from radiation from the Sun and other stars but also protects the Earth from the impact of meteors that every time they fall hitting Earth because these meteors generally burn out when they enter and rub against the atmosphere.[59]

3. Sun

The Sun is a celestial body in the form of an incandescent gas ball that is burning and very hot. The temperature of the Sun can reach 15 million degrees Celsius. The Sun is the closest star to Earth, with an average distance of 149,680,000 km (93,026,724 miles).[60]

The Sun is the center of our solar system and by far the dominant object in it. As well as providing the light and heat which power all life on Earth, it is by far the most massive object in the solar system: more than 300,000 times heavier than the Earth, and over 700 times heavier than all the planets put together. This huge mass acts as the anchor for the whole system: all of the other objects in the solar system - planets, asteroids, moons, etc. - are in orbit around the Sun, either directly, or indirectly as moons of other objects.[61]

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[59] Tono Saksono, *Mengkompromikan Rukyah & Hisab*, (Jakarta: Amythas Publicita 2007), 26.

[60] Slamet Hambali, *Pengantar Ilmu Falak*, 114.

[61] Ian Cameron Smith, "Hermit Eclipse", https://moonblink.info/Eclipse, accessed on 18 January 2021

The Sun is known as the center of the solar system where the eight planets surround it with their respective orbits and periods. The Sun is categorized as a small star type G which is 4.5 billion years old with a mass of 1.99x1030 kg which has a rotation period around the equator of 26 days. The Sun has several layers[62], namely: photosphere, chromosphere, and corona.

D. Geometry of Lunar Eclipse

The Moon circles the Earth once every 29.5 days, a period loosely coinciding with a month; the word "month," in fact, is derived from the German word for "moon." Twice each orbit, the Moon, Sun, and Earth line up approximately. The Earth orbits the Sun in a near-circle once every year, and the Moon orbits the Earth, reaching the Sun's position, every 29.5 days. However, the orbit of the Moon about the Earth and the Earth's orbit around the Sun is tilted by a small amount – about 5 degrees – relative to each other; if they were not, eclipses would happen every two weeks: a solar eclipse every new moon and a lunar eclipse at every full moon. Instead, the Moon spends part of its month-long orbit below the plane of the Earth's orbit around the Sun, and part of it above that plane. Twice each month the Moon crosses the plane of Earth's orbit. The two points of crossing, or intersection, of the two orbits, are called nodes.[63]

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[62] Slamet Hambali, *Pengantar Ilmu Falak*, 115-117.

[63] David H. Levi, *David Levy's Guide to Eclipses, Transits, and Occultation,* (New York: Cambridge University Press, 2010), 27.

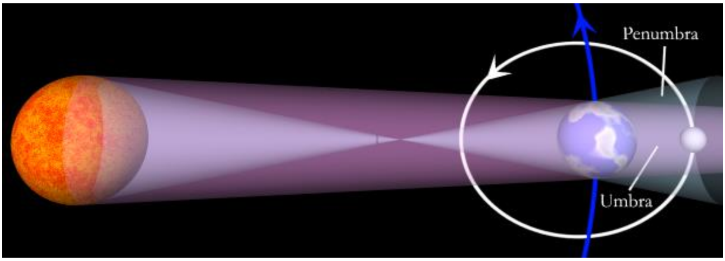

Figure 2.1 Shadow of Earth
(https://moonblink.info/Eclipse/why/lunar)

A lunar eclipse occurs when the Moon enters the shadow of Earth. Earth's dark shadow is about 1.4 million kilometers long, so at the Moon's distance (an average of 384,000 kilometers), it could cover about four full moons. Unlike a solar eclipse, which is visible only in certain local areas on Earth, a lunar eclipse is visible to everyone who can see the Moon. Because a lunar eclipse can be seen (weather permitting) from the entire night side of Earth, lunar eclipses are observed far more frequently from a given place on Earth than are solar eclipses.[64]

If the Moon is moving northwards in its orbit, it's called the ascending node; if it is going south, it crosses the descending node. The node crossings take place at different phases of the Moon each month. If these crossings take place near new or full moon, an eclipse can occur.[65]

The shadow formed by the Earth has two parts; first the outer part which is called the penumbra shadow or pseudo shadow (this shadow is not too dark), and the inner part which is called the umbra or the core image. The shape

[64] Andrew Fraknoi, et al, *Astronomy,* (Texas: Open Stax, 2016), 132.
[65] David H. Levi, *David,* 27.

of the circle of the Sun is larger than the circle of the Earth so that the image of the Earth's umbra forms a cone, while the shape of the Earth's penumbra is in the form of a cone truncated with its peak on Earth the farther the image is getting bigger until it disappears in space.[66]

In the *penumbra*, the light from the Sun is partly blocked by the Earth, but not completely, When the Moon passes through the penumbra, we see it dimming due to the reduced light, although in practice this can be hard to see with the eye. In the *umbra*, the light from the Sun is completely blocked by the Earth, we see the Moon darkened, but glowing a dull red from light scattered by the Earth's atmosphere. [67]

It is different with a solar eclipse where variations in the distance between Earth-Sun and Earth-Moon affect the type of eclipse, in a lunar eclipse, this variation only affects the size of the Earth's umbra and penumbra that the Moon crosses. This affects the duration (length) of the eclipse. If the Earth is in the closest distance to the Sun while the Moon is at its farthest distance from Earth and the Moon passes right in the middle of the umbra, the lunar eclipse that occurs is certain to be longer than the eclipses at other distances.[68]

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[66] Ahmad Izzuddin, *Ilmu Falak Praktis,* 107.

[67] Ian Cameron Smith, "Hermit Eclipse", https://moonblink.info/Eclipse, accessed on 18 January 2021

[68] Abdul Rachman, https://rachmanabdul.wordpress.com/2011/12/07/gerhana-bulan-dan-matahari/ accessed on 17 January 2021.

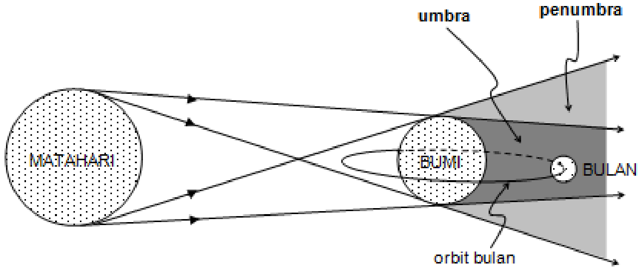

Figure 2.2 Total Lunar Eclipse

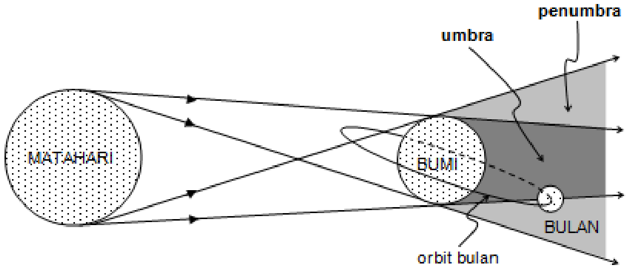

Figure 2.3 Partial Lunar Eclipse

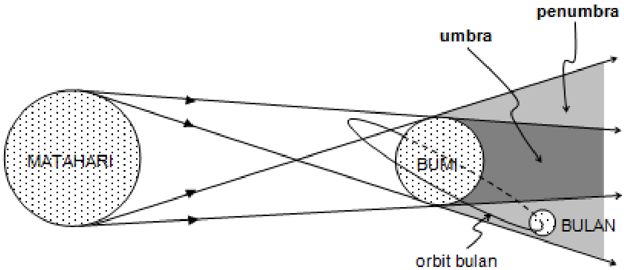

Figure 2.4 Penumbral Lunar Eclipse (https://rachmanabdul.wordpress.com/2011/12/07/gerhana-bulan-dan-matahari/)[69]

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[69] Matahari, Bumi, and Bulan is Indonesian Translation for Sun, Earth, and Moon. Look John M. Echols-Hasan Syadily, *Kamus Indonesia-Inggris*, Updated Edition, (Jakarta: PT Gramedia, 2014).

E. Types of Lunar Eclipse

Lunar eclipses are two kinds, - partial and total: total when she passes into the shadow completely; partial when she only partly enters it, going so far to the north or south of the center of the shadow that only a portion of her disc is obscured. We may also have a “penumbral eclipse” when she passes merely through the penumbra, without touching the shadow. In this case, however, the loss of light is so gradual and so slight, unless she almost grazes the shadow, that an observer would notice unusual.[70]

Overall, there are 3 kinds of lunar eclipses:[71]

1. Total Lunar Eclipse

   Total lunar eclipse is when the Moon is completely shadowed by the Earth. The Moon passes through the Earth’s umbra, and no direct light can reach it from the Sun. However, the Earth’s atmosphere refracts -- or bends -- light, at the same time filtering it, so that it illuminates the Moon with a dark red color. Depending on the prevailing condition of the Earth’s atmosphere, in terms of cloud cover and dust from volcanic eruptions, the actual color of the Moon at totality can vary from near black (particularly at mid-totality) to rust, brick red, or bright copper-red or even orange.

   A total lunar eclipse begins when the Moon enters the penumbra region. After that, little by little

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[70] Charles a Young, *A Text Book of General Astronomy*, 235.

[71] Ian Cameron Smith, “Hermit Eclipse”, https://moonblink.info/Eclipse, accessed on 18 January 2021.

parts of the Moon entered the umbra region. The duration of the Moon is in the umbra region, which is between 50 and 102 minutes. After passing through the umbra region, the Moon will re-enter the penumbra region and can reflect sunlight as before.[72]

When a total lunar eclipse begins, there will be four contacts;[73] the first contacts are when the disc of the Moon starts touching into the shadow of the Earth, on this is the position when the eclipse starts. The second contact, when the whole disk of the Moon has entered the Earth's shadow, is the position when it starts total eclipse. The third contact is when the Moon disc begins to touch to get out of the shadow of the Earth, at this position time the end of the total eclipse. The fourth contact, when the entire Moon disk is already out of the Earth's shadow, at this position the eclipse ends.

2. Partial Eclipse

In a partial lunar eclipse, part of the Moon is within the Earth's umbral shadow. From the Earth, we see the Moon partially in shadow, almost as if it wasn't full. In the later stages of a partial eclipse, as the Moon darkens, red coloration may become visible on the shadowed side of the Moon.

During a partial lunar eclipse, only a part of the Moon that is in the umbra becomes dark. There are two contacts in a lunar eclipse, namely: 1) The first contact,

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[72] Baharudin Zaenal, *Ilmu Falak*, first edition (Kuala Lumpur: Dawama Sdn. Bhd., 2002), 89.

[73] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktek,* 191-192.

when the lunar disc begins to touch the Earth's shadow, which marks the start of the eclipse. 2) The second contact is that the lunar disk has left the Earth's shadow, which marks the end of the eclipse.[74]

3. Penumbral Eclipse

In a penumbral eclipse, the Full Moon enters the Earth's penumbral shadow. The light from the Earth is partially blocked, and the Moon grows dimmer.

In principle, a penumbral eclipse can be a partial penumbral eclipse (with only part of the Moon in the penumbra) or a total penumbral eclipse, where the entire Moon is in the penumbra; however, most penumbral eclipses are partial, since the penumbral shadow of the Earth is only about as wide as the Moon, so it's rare for the Moon to fit entirely within the penumbra without entering the umbra (and hence making a partial umbral eclipse). Once in a while, though, it happens -- about 1.2% of all lunar eclipses are total penumbral eclipses. Most penumbral eclipses are pretty uninteresting since the Moon is still quite brightly lit, except in the most advanced stages. Still, in a deep penumbral eclipse, sharp-eyed observers should see a subtle but distinct shading across the Moon at maximum eclipse. This will be quite obvious in a total penumbral eclipse.

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[74] Sayful Mujab, "Gerhana: Antara Mitos, Sains dan Islam", *Yudisia*, vol. 5, no. 1, Juni 2014, 84-101.

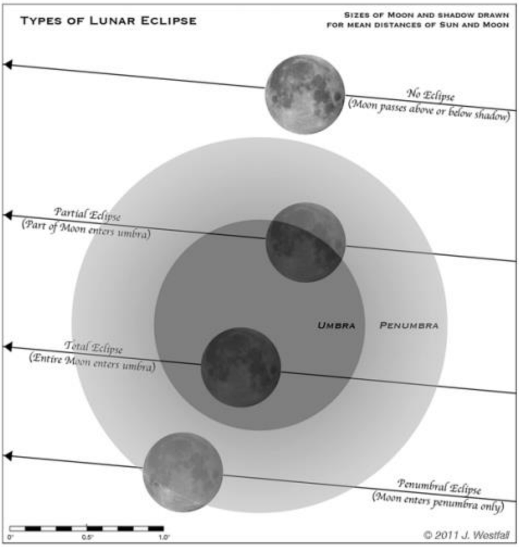

Figure 2.5 Types of Lunar Eclipses
(John Westfall, William Sheehan, Celestial Shadows Eclipses, Transits, and Occultation, (New York: Springer-Verlag, 2015), 50.)

F. Phases of the Moon

An eclipse is an astronomical event that cannot be separated from the problem of the phases of the Moon, because an eclipse occurs only when the Moon is in conjunction or when it is in opposition to the Sun.[75]

The Moon goes through a complete cycle of phases - from New to Full and back to New - in one orbit around the Earth; this is a lunar month, which is 29.5 days on average. This picture below shows how the Moon is illuminated by

[75] Ismail, "Lhokseumawe Society Rituals at the Solar Eclipse (Study of the Solar Eclipse March 9th 2016 and December 26th 2019), *Al-Hilal: Journal of Islamic Astronomy,* vol. 2, no. 1, 2020, 103.

the Sun at different times during a lunar month as the Moon orbits the Earth:[76]

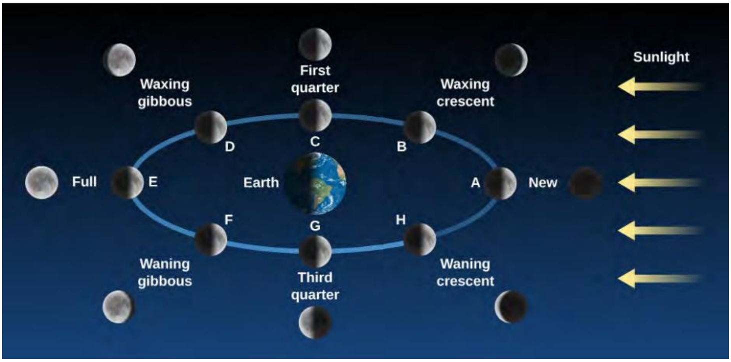

Figure 2.6 Phases of the Moon
(Andrew Fraknoi, et al, Astronomy, (Canada: D. Van Nostrand Company, 1955), 121.)

1. New Moon

   Starting at the New Moon, we can see that the Moon is on the same side of the Earth as the Sun. This means two things:

   a. The night side of the Earth is facing the wrong way to see the Moon. Because the Moon and Sun are in the same part of the sky as seen from Earth, if it's night - ie. the Sun is down - then the Moon must be down too. In other words, the Moon is only up (above the horizon) in the daytime. It rises at Sunrise, and sets at Sunset.

   b. The lit side of the Moon is turned away from Earth; the dark side is towards us. There is very little illumination on the dark side — there is the

[76] Ian Cameron Smith, "Hermit Eclipse", https://moonblink.info/Eclipse, accessed on 18 January 2021

reflected light from Earth, but that's much weaker than direct Sunlight — so the Moon is very dim.

The combination of these things - the Moon being dark, and only up in daytime - makes the New Moon pretty much impossible to see.

2. Waxing Crescent Moon

As the Moon continues anti-clockwise in its orbit, it moves around to the point marked First Quarter. Now, the term "quarter" here refers to the lunar month — we are a quarter of the way into the lunar month at this stage. However, looking at the diagram, you can see that people on the Earth looking "down" at the First Quarter Moon see part of the lit side, and part of the unlit side; in fact, what they see is a half Moon.

As you can see, the First Quarter Moon can be seen by some people on the daylight side of the Earth, as well as by some on the night side - in fact, the First Quarter Moon can be seen from noon, when it rises, through to midnight, when it sets if the sky is clear enough.

3. Waxing Gibbous Moon

As the Moon moves on, it keeps growing and becomes a gibbous Moon, which is a half Moon with a bulge - partway between a half Moon and Full Moon.

4. Full Moon

At the next stage, we can see that the Moon is on the opposite side of the Earth from the Sun. This means two things: the dark side of the Earth - which is to say, the part which is currently in the night-time - is the part which can see the Moon; and it sees the whole lit side of the Moon. This is a Full Moon, which rises at sunset, and sets at Sunrise. We are now halfway through a lunar month

5. Waning Gibbous Moon

   The second half of the lunar month is the reverse of the first half. As the Moon moves past Full, it starts to shrink, becoming a gibbous Moon; this time, the waning gibbous Moon, as it's shrinking ("waning"). This Moon is visible from early night-time to mid-morning if the sky is clear enough to see it in daytime.

6. Last Quarter

   The Moon again reaches the half-Moon stage at Last Quarter (the last quarter of the lunar month). At this stage, we again see half the Moonlit, and again the Moon is visible from both the day and night sides of the Earth; looking at the diagram above, you'll see that the Moon is visible from the midnight point to Sunrise, through to noon.

7. Waning Crescent Moon

   After the Last Quarter, the Moon diminishes once again to a crescent, now visible from just before dawn through to afternoon; this is the waning crescent Moon.

8. New Moon

   Finally, the crescent Moon shrinks to nothing at the next New Moon, and the cycle starts all over again.

G. Periodicity of Lunar Eclipse

The periodicity and recurrence of eclipses are governed by the Saros Cycle[77], a period of approximately 6,585.3 days (18 years 11 days 8 hours). Eclipses may repeatedly occur, separated by certain intervals of time: these intervals are called eclipse cycles. The series of eclipses separated by a repeat of one of these intervals is called an eclipse series. The series has characteristics, as follows: [78]

1. Synodic month is the time required by the month for two consecutive *ijtimā'* (conjunctions) for 29,53059 days or equivalent to 29 days 12 hours 44 minutes 02.8 seconds.
2. Eclipse year is the interval of 346,62 days or equivalent to 346 days 14 hours 24 minutes sidereal days between two successive conjunctions of the Sun with the same node of the Moon's orbit.
3. Anomalistic month is a month measured between successive perigees of the Moon being approximately 27.55455 days or 27 days 13 hours 19 minutes.

Eclipses separated by 233 synodic moons will have the same characteristics. Since 233 synodic months are roughly the same as 19 years of eclipse, they are only 11 hours apart. This means that at the interval of one period the

[77] Saros is a time interval of 18 years and 11 days. At the time of saros, the moon and sun occupy the same position, therefore the lunar or solar eclipse will be repeated every 18 years and 11 days. Look Muhyiddin Khazin, *Kamus,* 72.

[78] Ahmad Izzuddin, *Ilmu Falak Praktis,* 111.

Moon's saros will return to the same phase and the same node point as well.[79]

The impact of this saros period will result in the length of the day having a fraction of 1/3 day (8 hours). So the next eclipse which has been separated by a Saros period, the Earth has rotated for 1/3 of the day. Therefore, the eclipse trajectory will shift 120 degrees to the west. And what's unique is that every 3 periods of Saros (54 years 34 days) an eclipse can be observed in the same geography. However, this Saros series does not last forever. But birth and death one after another. Saros series does not last long because the saros period is shorter than 19 years eclipse. As a result, the node of one saros period will shift to the east by 5 degrees so that the distance of the vertices is so far from the Sun or the Moon that it is no longer possible for an eclipse to occur. At this time the respective saros series will die and a new saros series will be born.[80]

The Saros series of lunar eclipses will begin when there is a full moon with a distance of 16.5 degrees east of the node. When the Saros series occurs then the lunar eclipse:[81]

1. The full Moon eclipse that occurs is a penumbra (pseudo) eclipse which will be followed by another penumbra eclipse with a total of around 7-15 penumbra eclipses. From a penumbra eclipse to the next penumbra eclipse, the magnitude of the Moon will increase little

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[79] Ibid., 113.
[80] Ahmad Izzuddin, *Ilmu Falak Praktis,* 155.
[81] Ibid., 112.

by little. This is because one saros period is shorter than 19 eclipse years, this results in after one saros period the vertex will shift to the east by 0.5 degrees and will automatically shift the magnitude of the next penumbra eclipse until the Moon approaches the Earth's penumbra.

2. Next, there will be 10-20 partial lunar eclipses with increasing magnitude. Until finally the entire Moon disc will enter the shadow region of the Earth's umbra.
3. Next, there will be 12-30 total lunar eclipses by an increase in the distance of the Moon to the west from the center of the Earth's shadow.
4. Furthermore, there will be 10-20 partial lunar eclipses and the eclipse magnitude will decrease to the next eclipse.
5. The saros series will end at about 16.5 degrees west of the node after 7-15 penumbra eclipses.

One series of lunar eclipses takes about 13-14 centuries from birth to death. Each Saros series consists of 70-85 lunar eclipses and 45-55 umbra eclipses.[82] Apart from the Saros period, there is also the Tritos period which has a period of 135 lunations (11 years less than 1 month). There is also a Matins Cycle with has a period of 235 lunations or

[82] Setiyani, "Perspektif Tokoh-Tokoh Ilmu Falak Tentang Fenoena Gerhana Bulan Penumbra dan Implikasinya Terhadap Pelaksanaan *Shalat Khusuf*", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2018), 32.

approximately 19 years and others. But so far, the period we always use is the Saros series that has been described above.[83]

H. Classification of Lunar Eclipse Calculation Method

Algorithm is a set of rules that must be followed when solving a particular problem.[84] There are two algorithms in the reckoning of a lunar eclipse that can be mentioned to represent the thought of reckoning in Indonesia; *hisāb' urfiy* and *hisāb haqiqi*.[85]

Hisāb' urfiy is a calculation of the beginning of the month based on the age of the month which applies conventionally.[86] This system of reckoning is like the *Shamsiah (Miladiyah)* calendar system[87], where the number of days in each month is fixed unless certain months in certain years are set to be one day longer. So that this system of reckoning cannot be used in determining the beginning of the lunar month for the implementation of worship (beginning and end of Ramadan) because according to this system the age of the months of Sha'ban[88] and Ramadan[89] is

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[83] Rinto Anugraha, *Mekanika Benda Langit*, (Yogyakarta: Jurusan Fisika Fakultas MIPA UGM, 2012), 129.

[84]Oxford, "Oxford Advanced Learner's Dictionary", https://www.oxfordlearnersdictionaries.com/, accessed on 16 January 2021.

[85] Susiknan Azhari, *Pembaharuan Pemikiran Hisab di Indonesia*, (Yogyakarta: Pustaka Pelajar, 2002), 23.

[86] Muhyiddin Khazin, *Kamus*, 88.

[87] Also called the solar calendar. The *shamsiyah* calendar is a calendar based on the rotation of the earth around the sun. Look Muhyiddin Khazin, *Kamus*, 77.

[88] Eighth Arabian Month. Look Hava J., *Arabic-English Dictionary*, 357.

[89] Ninth Arabian Month: Fasting moon for Muslim. Look Hava J., *Arabic-English Dictionary*, 262.

fixed, namely 29 days for Sha'ban and 30 days for Ramadan.[90]

Meanwhile, *hisāb haqiqi* is a calculation of the position of celestial bodies based on their average motion, so that the results are approximate.[91] According to this system, the age of each month is neither constant nor irregular but depends on the position of the new Moon at the beginning of the month. There will be a possibility that two consecutive months are 29 days or 30 days old, and it may also change according to the *hisāb' urfiy*. This system uses astronomical data and the movements of the Moon and Earth and uses the rules of measuring spherical trigonometry.[92]

The system *of hisāb haqiqi* is divided into three;[93] the *hisāb haqiqi bi at-taqrib*, *hisāb haqiqi bi at-tahqiq* and *hisāb haqiqi contemporary*:

Haqiqi taqriby is a system of calculating the position of celestial bodies based on the average motion of the celestial bodies themselves so that the results are estimates or approach the truth.[94] This method uses data from the Sun and Moon based on astronomical data and tables such as the data from the observations of *Zij Sulthani* by Ulugh Bek[95] with a simple calculation process. This reckoning is only done by

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[90] Susiknan Azhari, *Ensiklopedi,* 79-80.
[91] Ibid., 28.
[92] Susiknan Azhari, *Ensiklopedi,* 78.
[93]Ahmad Izzuddin, *Fiqih,* 7.
[94] Muhyiddin Khazin, *Kamus,* 28.
[95] Astronomers born in Salatin (1393 AD) and died in Alexandria (1449 AD) with his observatory he succeeded in compiling astronomical data tables which were widely used in the development of astronomy in later times. Look Muhyiddin Khazin, *Kamus,*117.

adding, subtracting, multiplying, and dividing without the use of spherical trigonometry measurement. Among the books included in this category are *Sullam an-Nayirain* by Muhammad Mansur al-Battani and *Shamsul Hilal* by Nor Ahmad.[96]

Hisāb bi at-tahqīq is the calculation based on astronomical data processed with spherical trigonometry with precise corrections for the motion of the Moon and the Sun.[97] This method is the result of an extract from the book *Al-Mathla' as-Said Rushd al-Jadid* which is rooted in modern astronomical and mathematical systems whose origins are from the computation system of ancient Muslim astronomers and have been developed by modern astronomers (western astronomers). Based on new research the essence of this system is to calculate or determine the position of the Sun, Moon, and the vertices of the Moon's orbit with the Sun's orbit in the ecliptic coordinate system. This means that this system uses corrected tables and the calculations are relatively complicated than the *haqiqy taqriby* method. Among the books that use this method are *Khulāṣah al-Wāfiyah* by Zubair Umar al-Jaelani and *Nūr al-Anwār* by Noor Ahmad.[98]

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[96] Rizqi Raukhillahi, "Analisis Metode Hisab Gerhana Bulan Dalam Kitab Tibyanul Murid 'Ala Zijil Jadid Karya Ali Mustofa", *Undergraduate Thesis* UIN Walisongo Semarang (Semarang, 2019), 27, not published.

[97] Syaiful Mujab, "Studi Analisis Pemikiran Hisab KH. Moh. Zubair Abdul Karim dalam Kitab *Ittifaq Dzatil Bain*", *Undergraduated Thesis* UIN Walisongo Semarang (Perpustakaan IAIN Walisongo Semarang, 2007), 9-10.

[98] Rizqi Raukhillahi, "Analisis Metode", 27.

The last method is the *haqiqi* contemporary method. This method uses the results of the latest research and uses mathematics that has been developed. The method is the same as the *haqiqi bi at-tahqiq* method, it's just that the correction system is more precise and complex in accordance with the development of science and technology. Contemporary essential rationale, this group of systems in theory and its application has used computerized media and sophisticated equipment such as compass, theodolite, GPS, and so on. In calculating the computation data using very complicated formulas in addition to using the theory of spherical trigonometry measurement, all the computation data is programmed through a computerized device to minimize errors in calculations and the accuracy of the calculation results is in accordance with the reality at the observation site.[99]

[99] Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan", 51.

CHAPTER III
THE CALCULATION METHOD OF LUNAR ECLIPSE IN THE BOOK OF *RISĀLAH AZ-ZAIN* BY IBN YA'QŪB AL-BATĀWY

A. Intellectual Biographies of Ibn Ya'qūb al-Batāwy

Ibn Ya'qūb al-Batāwy is an astronomer from the capital city of Indonesia, Jakarta, and his address at Malaka II Street, Rorotan Cilicing, North Jakarta. Ibn Ya'qūb al-Batāwy is the only child of Siti Kurnia and Abdul Rohman, who was born on October 24, 1992 in Jakarta.

The name Ibn Ya'qūb is the name his grandfather gave to his grandchildren when he was born, while al-Batāwy is the name of his birthplace which comes from the Betawi tribe. Ibn Ya'qūb al-Batāwy also has another name, namely Ikhwanudin which is the name given to him by his parents. Because in honor of his grandfather who had educated him since childhood, Ibn Ya'qūb al-Batāwy wrote the name his grandfather had given him in each of his books.

Ibn Ya'qūb al-Batāwy started his formal education at 06 Jakarta in 1999-2005 Elementary School and continued to MTs[1] and MA[2] al-Jauharotun Naqiyyah in 2006-2012 and finally at the Islamic Institute of Tribakti IAIT Kediri in 2016-2020. In addition to taking academic education, Ibn

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[1] MTs or *Madrasah Tsanawiyah* is the Islamic schooling equivalent of SMP (Middle School).

[2] MA or *Madrasah Aliyah* is the Islamic Schooling equivalent of SMA (High School).

Ya'qūb al-Batāwy also took education at the Islamic boarding school, Ibn Ya'qūb al-Batāwy started his education at the Pesantren[3] from 2005-2013 at the Roudlotul Mubtadi'in Islamic Boarding School in Cibeber, then Ibn Ya'qūb al-Batāwy continued the *Riḥlah' Ilmiyyah*[4] at the Hidayatul Mubtadi Islamic Boarding School Lirboyo Kediri in 2013-2020. Then Ibn Ya'qūb al-Batāwy married a woman named Khoirun Nisa and was blessed with a son named Ahmad Daniel Kafa.

Ibn Ya'qūb al-Batāwy has long been fond of the science of Falak and has been devoted to it since he was in the Islamic boarding school, finally Ibn Ya'qūb al-Batāwy expressed all his passion into thought in the form of book, such us: *Data Ḥisab Era Rosulullah SAW 53 SH-11 H, Katalog Satu Abad Fase Bulan dan Gerhana 1440-1540, Ḥisab Taqrīby Sulam an-Nayroin, Risālah al-Manzilah*, and *Risālah az-Zain* written in 2020.

Data Hisab Era Rosulullah SAW contains data on the movement of celestial bodies, especially the Sun and Moon, that occurred during the year 53 before Hijriyah to 11 AH in the City of Mecca and the City of Medina. These data are in

[3] *Pesantren* or *Pondok Pesantren* are Islamic boarding schools in Indonesia. They consist of *pondok* (dormitories), mosque, *santri* (students), teaching of classical Islamic text and teaching by Kyai atau guru keagamaan. Pesantren aim to deepen knowledge of the Qur'an and Hadits, particularly through study basic skills of reading and writing Arabic, learning Islamic law and ritual.

[4] *Rihlah 'Ilmiyyah* comes from Arabic which means any activities that are aimed to migrate from one place to other ones which is aim to develop and to comprehend Islamic science mastery of *santri* (students who study in *pondok pesantren*) for the sake of Islamic scholarship they will experience in the future.

the form of latitude and longitude for the cities of Mecca and Medina, dynamic time (TD), sunset time (Set^{o}), Sun height (Al^{o}), Sun azimuth (Az^{o}), elongation (El), hilal light in percent. (Fl), the time of setting of the Moon (Set^{C}), the height of the geocentric Moon (Al^{G}), the azimuth of the Moon (Az^{C}), the height of the lower topocentric Moon (Al^{TL}), the height of the upper topocentric Moon (Al^{TU}). These data are used to determine the time of important and historic events experienced by the Prophet Muhammad SAW, such as the birth, death, and hijrah of the Prophet Muhammad from the city of Mecca to Medina.

Katalog Satu Abad Fase Bulan dan Gerhana 1440-1540 contains data on the phases of the Moon (neap 1, full moon, neap II, and conjunction) and eclipses for a century from 1440-1540 based on the Greenwich time zone. This catalog contains tables of Hijri years, AD, days, *pasaran*, and the phenomenon of lunar and solar eclipses.

Risālah al-Manzilah contains the definition of the Qibla, the calculation of the direction of the Qibla. Time calculations related to worship such as *Fajr, Zuhr, Asr, Maghrib, Isha, Dhuha, Thulu*, the beginning of the night, the middle of the night, and the end of the night. This book contains formulas and examples of calculations using calculator. And lastly, *Risālah az-Zain*, a book that will be discussed further in this thesis.

On the other hand, Ibn Ya'qūb al-Batāwy also often participates in training and seminars both held by certain institutions or academics, Ibn Ya'qūb al-Batāwy has also been a tutor for teaching Falak Science at Cibeber Boarding

School and a member of Lajnah Falakiyah[5] Lirboyo Boarding School, now Ibn Ya'qūb al-Batāwy serves as PRNU[6] Rorotan North Jakarta.

B. General View of the Book of the *Risālah az-Zain*

Risalah az-Zain is a book written by Ikhwanudin who has the pen name Ibn Ya'qūb al-Batāwy. In general, this book has 3 main discussions: the method of calculating the beginning of the Hijri month, calculating the solar eclipse, and calculating the lunar eclipse. This book was compiled in 2020 using contemporary calculations based on one of the Microsoft Office programs, Microsoft Excel, to make calculations more easier. As is well known, the method of reckoning lunar and solar eclipses has a long calculation with many correction values which are still considered burdensome for some people even with the help of a calculator. Therefore, Ibn Ya'qūb al-Batāwy had the idea to create a method of calculating the beginning of the Hijri month, calculating solar eclipses, and calculating lunar eclipses that are more concise and precise.

The process of compiling the book *Risālah az-Zain* Ibn Ya'qūb al-Batāwy refers to the calculations of Jean Meeus and the books written by his teachers which were then developed with their own thoughts so that the book *Risālah*

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[5] Lajnah Falakiyah comes from Arabic which means an organizational tool for implementing programs that require special handling of *isbat* and *rukyah* issues as well as the development of Falak Science.

[6] PRNU stands for Pengurus Ranting Nahdlatul Ulama (Nahdlatul Ulama Branch Management) which is the management of the Nahdlatul Ulama Islamic Community Organization that works at the village level.

az-Zain was created. The book method using the Microsoft Excel program make the calculation of the beginning of the Hijri month, the calculation of a solar eclipse, and the calculation of a lunar eclipse are easier and more concise than calculations using long algorithms and long correction terms such as Jean Meeus and the calculation methods of classical books.

The book of *Risālah az-Zain* consists of 47 pages including appendices which are divided into 5 chapters, a simple explanation of the discussion contained in the book *Risālah az-Zain* is as follows:[7]

1. *Awjah al-Qamar* (Phases of the Moon)

   This chapter discusses the phases of the moon such as determining the time of conjunction and the opposition of the moon, the 1st quarter and 2nd quarter of the month and calculating the beginning, middle and end of the month in the Islamic calendar.

2. *Harakāt an-Nayyiroin* (Movement of Two Light)[8]

   This chapter discusses the movements of the sun and moon when the conjunction occurs in the Islamic calendar. The calculations in this chapter aim to determine the position of the sun and moon, their specific location and position, and the light that is formed.

3. *Harakah as-Shams* (Sun Movement)

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[7] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain*, (Jakarta: 2020), 46, not published.

[8] Term "Two light" in Arabic means the Sun and the Moon.

This chapter will discuss specifically and in detail about the calculation of the Sun movement which will later affect the determination of worship.

4. *Harakah al-Qomar* (Moon Movement)

   Just like chapter 3, this chapter will discuss specifically and in detail about the calculation of the Moon movement which will be the basis for the formation of the Hijri calendar and the determination of the beginning of the Hijri month.

5. *Al-Kusūfaini* (Two Eclipses)

   This chapter discusses the phenomenon of eclipses, both solar and lunar eclipses. From this chapter we can find out the types of eclipses: total, partial, and annual eclipses for the Sun as well as penumbra, partial, and total eclipses for the Moon.

Introduction to Excel[9]

As we know, Microsoft Excel or more commonly known as Excel is one of the software included in the Microsoft Office package. Microsoft Excel is an application created and distributed by Microsoft Corporation that can be used for Windows operating systems as well as Mac OS. Microsoft Excel functions to process numbers using a spreadsheet consisting of rows and columns to execute commands. This software is quite famous in number processing because of its simple way of using it with the Formulas and Functions features. These Formulas and

[9] Blog Tutorial Microsoft Excel Indonesia, https://www.kelasexcel.id/, accessed on 4 May 2021

Functions function to perform various data calculation processes in a fast, precise, and semi-automatic manner. This formula can be used to complete simple calculations to complex calculations, whether for data in the form of numbers, text, dates, times, or a combination of these data.

Microsoft Excel works with a workbook system, which includes a worksheet which is usually simply called a sheet. On this sheet, there are columns and rows that form small boxes for entering data called cells. Excel is equipped with the Visual Basic for Applications (VBA) programming language so that we can add Excel's ability to automate calculations and we can also add user-defined functions (UDF) to be applied in the worksheet. This UDF makes it easy for users to design functions that can be tailored to the wishes and needs of each user.

Ibn Ya'qūb al-Batāwy chose to use the Excel program in his *Risālah az-Zain*, because this program is the right choice for processing numbers in the calculation of the beginning of the Hijri month, calculating solar eclipses, and calculating lunar eclipses. We can create, edit, sort, analyze and summarize data from what happens in the field into worksheets. These worksheets can make arithmetic and statistical calculations easier and solve logic and math problems. With the existence of organized data, it will be easier to perform calculation analysis, make conclusions and visual data presentation of phenomena that occur in the field.

Doing calculations with Excel is much easier than using a calculator, but it depends on the user's understanding and skill in applying Excel formulas. If the user makes a mistake during the data input process, it will result in overall misinformation. Therefore, users must be careful when entering data, numbers and Excel formulas.

Excel Formulas and Functions

Excel formulas are mathematical equations for calculating certain values in order to get the expected results from Excel. Excel formulas always begin with an equal sign (=). In an Excel formula there are Excel functions, references, constants and basic operators in Microsoft Excel. Excel formulas are different from Excel functions. Excel functions are preset of formulas that aim to simplify formulas to make the data calculation process shorter and relatively easier to work with.

The parts of an Excel formula, in general, can be explained by the following examples:

=SUM(A3:C6)/D14*8

1. Equals sign (=): initial sign of writing Excel formulas before using any formulas.
2. SUM: is an Excel function which is a specific code that performs certain calculations in Excel based on the arguments set by Microsoft Excel. SUM itself is one of many Excel functions that are used to add the data up.
3. A3:C6: Reference to a range
   D14: Reference to a single cell
   Reference refers to a cell or range on a worksheet.

4. / and *: Operator. Operators are symbolic characters that define the type of calculation to be performed. / for division dan * for multiplication
5. 8: Constant. A constant is a data value that is not the result of a calculation so that the value is always the same or does not change.

The parts of Excel functions, in general, can be explained by the following examples:

=IF(M3>D12;“Total”;”Sebagian”)

1. Equal sign (=): the initial sign of writing the Excel function followed by the name of the function.
2. IF: Function name. For a list of existing functions, click on a cell and press shift + F3.
3. M3=D12: Argument 1
   “Total”: Argument 2
   “Sebagian”: Argument 3
   Arguments can be numbers, text, logical values, which will return a valid value for that argument. Each argument is separated by a comma (,) or a semicolon (:) according to the computer settings used. For this example, if the value in cell M3 is greater than the data in cell D12 then there is a possibility that a total or a partial eclipse will occur.

The formulas and functions used in the book *Risālah az-Zain* are as follows:

1. SUM: to add up data

2. SIN: to returns the sinus value from entered data
3. ABS: to returns the absolute value or positive value of an entered numeric value
4. RADIANS: to converts the angle value from degrees to radians
5. INT: to rounds a number down to the integer or nearest integer
6. IF: to makes logical comparisons between values and what to expect by testing the condition and returning the result if it is True or False. IF statements can have two or more results
7. COS: to calculates the cos value from numeric data which is the angle value expressed in radian
8. MOD: to get the remainder for dividing a number
9. SQRT: to get the result of calculating the square root of a number
10. CHOOSE: to select a value from a set of value arguments based on a specific index number or sequence

The math operator used in the book *Risālah az-Zain* are as follows:

1. + (Plus) : Addition
2. – (Minus) : Subtraction, negation
3. * (Asterisk) : Multiplication
4. / (Forward Slash) : Division
5. ^ (Caret) : Powers of numbers

In the last sheet of this book, the author lists a table containing symbols and terms used in the calculation process. The terms table consists of 3 languages: English, Arabic and Indonesian. The symbols and abbreviations used are as follows:[10]

Symbols	English	Indonesia	Arabic
	Motion	Pergerakan	الحركة
	Ecliptic	Ekliptika	الدائرة البروجية
θº	Sidereal Time	Waktu Sideris	الوقت النجمي
Lº/ L'	Mean Longitude	Bujur Rata-rata	الطول الوسطي
D	Mean Elongation	Elongasi Rata-rata	فضل الوسط
M/ M'	Mean Anomaly	Anomali Rata-rata	الخآصة
F	Argument of Latitude	Argumen Lintang	حصة العرض
Ω	Nodes of Moon	Nodal Bulan	عقدة القمر
Δψ	Nutation in Longitude	Nutasi Bujur	التمايل في الطول
Δε	Nutation in Obliquity	Nutasi Kemiringan Ekliptika	التمايل في ميل الكلي

[10] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain, 47.*

εo	Obliquity	Kemiringan Ekliptika	**ميل الكلي**
E	Eccentricity	Eksentrisitas	**الإختلاف المركزي**
λ°.λ'	Apparent Longitude	Bujur Tampak	**طول الظاهري**
β.β'	Apparent Latitude	Lintang Tampak	**عرض الظاهري**
R	Radius Vector	Vektor Radius	**نصف القطر المُ وجَّة**
δ	Declination	Deklinasi	**الميل**
α	Right Ascension	Asensio Rekta	**المطلع المستقيم**
Π.P	Horizontal Parallax	Horisontal Paralaks	**إختلاف المنظر**
S	Semi Diameter	Semidiameter	**نصف القطر**
e	Equation of Time	Prata Waktu	**تعديل الوقت**
A.h	Altitude	Tinggi	**الإرتفاع**
H.Ha.Hb	Hour Angle	Sudut Waktu	**زاوية الوقت**
Z	Azimuth	Azimut	**السمت**
Set	Setting	Terbenam	**الغروب**
ψ	Elongation	Elongasi	**زاوية الإستطالة**
K.K'	Illumination Fraction	Fraksi Iluminasi	**نور الهلال**

Ref	Refraction	Refraksi	انكسار الشعاع
ϒ	Gamma	Gama	بعد الظل
u	Magnitude	Magnitudo	نصف قطر الظل

Table 3.2 The Symbols and Terms in the Book Risālah az-Zain

C. Algorithm of Calculating of Lunar Eclipse in The Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

The lunar eclipse reckoning algorithm used in the book Risālah az-Zain uses the Jean Meus Algorithm but there are some formulas that are different such as calculating the value of K (estimated year of the eclipse), simplification of the formula F (argument for the latitude of the Moon), formula for calculating the value of A (additional correction to get the value of C), correction formula to determine the value of C (time of maximum eclipse), and additional determination of *Pasaran* when the eclipse occurs.

Even though this lunar eclipse occurs during the full Moon, this lunar eclipse does not occur every month. This is because the Moon's orbit around the earth is not the same as the earth's orbit around the Sun. The Moon's orbit is not in line with the earth's orbit, but the Moon's orbit intersects the earth's orbit and forms an angle of 5^o.

With a 5^o inclination of the lunar orbital plane to the ecliptic plane, the Moon can be above or below the Earth's shadow area when the Moon is full. Likewise, the earth can be above or in the Moon's shadow during the new Moon. So a lunar eclipse will only occur if the Moon is near the point where the orbits of the Moon and the earth meet which are called the vertex.[11]

Remember that a lunar eclipse will only occur when the Moon is full, around the 15th of the lunar month. So what has to be done is to calculate the 15th day of the month where there is a possibility of a lunar eclipse and the exact date according to the Solar calendar. Then prepare the astronomical data for the Solar date as needed.

The steps for calculating a lunar eclipse in *Risālah az-Zain*'s Treatise book, are as follows:

1. Determine the approximate year (Y) and the month prediction (M) of the lunar eclipse in the Hijri calendar.[12]
2. Determine Time Zone (TZ)
   Under the condition: WIB = 7, WITA = 8, WIT = 9
3. Calculating the Hijri Year (Y) on the date when the eclipse is predicted to occur.
   Estimated year (Y) = year + (months that have passed / 12)
4. Calculating the value of K
   Estimated value of K = (Y – 1420,75) x 12 – 0,5
5. Calculating the value of T, with the formula:
   T = K / 1236,85
6. Calculate the Julian Day Ephemeris 13 (JDE), with the formula: [14]

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[11] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain*, 28.
[12] *Ibid.*

JDE = 2451550,09766 + 29,530588861 x k + 0,00015437 x T^2 - 0,00000015 x T^3 + 0,00000000073 x T^4

7. Calculate Sun's mean anomaly (M), with the formula:
   M = 2,5534 + 29,1053567 x K – 0,0000014 x T^2 - 0,00000011 x T^3
8. Calculate the Moon's mean anomaly (M'), with the formula:
   M' = 201,5643 + 385,81693528 x K + 0,0107582 x T^2 +0,00001238 x T^3 - 0,000000058 x T^4
9. Calculate the astronomical longitude of the Moon from the ascending node (omega/Ω), with the formula:
   Ω = 124,7746 – 1,56375588 x K+ 0,0020672 x T^2 + 0,00000215 x T^3
10. Calculate the argument value for the latitude of the Moon (F), with the formula:
    F = 160,7108 + 390,67050284 x K – 0,0016118 x T^2 - 0,00000227 x T^3 + 0,000000011 x T^4 – 0,026665 x sin Ω
11. Determine the probability of an eclipse, with Excel formula:
    Imkan = IF (ABS(SIN(RADIANS(F))) < 0,3588, "M", "T")
    Eclipse has the possibility to occur if the value of Imkan is less than 0.3588

---

[13] JDE is the time of the new moon (time that need to be found) which is stated in Julian Day.

[14] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain,* 29.

12. Calculating the eccentricity value of the Earth's orbit around the Sun (E), with formula:
    $E = 1 – 0,002561 \times T – 0,0000074 \times T^2$
13. Calculate the value of A, with formula:
    $A = 0,0003 \times \sin (299,77 + 0,107408 \times K – 0,009173 \times T^2)$
    With Excel formula:
    A = 0,0003 * SIN(RADIANS(299,77 + 0,107408 * K – 0,009173 x T²))
14. Calculate corrections to find out the middle of the eclipse (C):
    a. Calculate the value of C1, with formula:
       $C1 = -0,4065 \times \sin M'$
       With Excel formula:
       C1 = -0,4065 * SIN(RADIANS(M’))
    b. Calculate the value of C2, with formula:
       $C2 = 0,1727 \times E \times \sin M$
       With Excel formula:
       C2 = 0,1727 * E * SIN(RADIANS(M))
    c. Calculate the value of C3, with formula:
       $C3 = 0,0161 \times \sin 2M'$
       With Excel formula:
       C3 = 0,0161 * SIN(RADIANS(2*M’))
    d. Calculate the value of C4, with formula:
       $C4 = 0,0097 \times \sin 2F$
       With Excel formula:
       C4 = 0,0097 * SIN(RADIANS(2*F))
    e. Calculate the value of C5, with formula:
       $C5 = 0,0073 \times E \times \sin (M'-M)$

With Excel formula:

C5 = 0,0073 * E * SIN(RADIANS(M’-M))

f. Calculate the value of C6, with formula:

C6 = -0,0050 x E x sin (M’+M)

With Excel formula:

C6 = -0,0050 * E * SIN(RADIANS(M’+M))

g. Calculate the value of C7, with formula:

C7 = -0,0023 x sin (M’-2F)

With Excel formula:

C7 = -0,0023 * SIN(RADIANS(M’-2*F))

h. Calculate the value of C8, with formula:

C8 = 0,0021 x E x sin 2M

With Excel formula:

C8 = 0,0021 * E * SIN(RADIANS(2*M))

i. Calculate the value of C9, with formula:

C9 = 0,0012 x sin (M’+2F)

With Excel formula:

C9 = 0,0012 * SIN(RADIANS(M’+2*F))

j. Calculate the value of C10, with formula:

C10 = 0,0006 x E x sin (2M’+M)

With Excel formula:

C10 =0,0006 * E * SIN(RADIANS(2*M’+M)

k. Calculate the value of C11, with formula:

C11 = -0,0004 x sin 3M’

With Excel formula:

C11 = -0,0004 * SIN(RADIANS(3*M’))

l. Calculate the value of C12, with formula:

C12 = -0,0003 x E x sin (M+2F)

With Excel formula:

C12 = -0,0003 * E * SIN(RADIANS(M+2*F))

m. Calculate the value of C13, with formula:

C13 = -0,0002 x E x sin (M-2F)

With Excel formula:

C13 = -0,0002 * E * SIN(RADIANS(M-2*F))

n. Calculate the value of C14, with formula:

C14 = -0,0002 x E x sin (2M'-M)

With Excel formula:

C14 = -0,0002 * E * SIN(RADIANS(2*M'-M))

o. Calculate the value of C15, with formula:

C15 = -0,0002 x sin Ω

With Excel formula:

C15 = -0,0002 * SIN(RADIANS(Ω))

p. Calculate the value of C, with formula:

C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 + C12 + C13 + C14 + C15

With Excel formula:

C =SUM (First Data: Last Data)

The first data is the data in the first cell that we will add up, data in C1

The last data is the data in the last cell that we will add up, data in C15

Excel will immediately add up the data from C1 to C15

15. Calculating the Julian Day Ephemeris date (JDE TD), with formula:

JDE TD = JDE + A + C + 0,5

16. Calculating the Julian date adjusted to the time of the area (JDE WD), with formula:

JDE WD = JDE TD + TZ / 24

17. Calculating Greenwich Mean Time (GMT), with Excel formula:
    GMT = (JDE TD - INT(JDE TD))*24
18. Calculating the time of the area (WD), with Excel formula:
    WD = (JDE WD - INT(JDE WD))*24
19. Calculate the value of Z, with Excel formula:
    Z = INT(JDE WD)
20. Calculate the value of α, with Excel formula:
    α = INT((Z- 1867216,25) / 36524,25)
21. Calculate the value of A, with Excel formula:
    A =IF(Z<2299161;Z;Z+1+ α -INT(α /4))
22. Calculate the value of B, with Excel formula:
    B = A + 1524
23. Calculate the value of C, with Excel formula:
    C = INT((B - 122,1) / 365,25)
24. Calculate the value of D, with Excel formula:
    D = INT(365,25 *C)
25. Calculate the value of E, with Excel formula:
    E = INT((B -D) / 30,6001)
26. Determine the date of the lunar eclipse, with Excel formula:
    TGL =B-D-INT(30,6001*E)
27. Determine the month of the lunar eclipse, with Excel formula:
    BLN =IF(E>=14;E-13;E-1)
28. Determine the year of the lunar eclipse, with Excel formula:

THN =IF(BLN<=2;C-4715;C-4716)

29. Determine the days when the eclipse occurs (HA), with Excel formula:
    HA =MOD(Z+2;7)
30. Determine the pasaran[15] when the eclipse occurs (Pa), with Excel formula:
    Pa =MOD(Z+1;5)
31. Calculate the value of P, with the following corrections:[16]
    a. P1, with formula:
       P1 = 0,2070 x E x sin M
       With Excel formula:
       P1 =0,207*E*SIN(RADIANS(M))
    b. Calculate the value of P2, with formula:
       P2 = 0,0024 x E x sin 2M
       With Excel formula:
       P2 =0,0024*E*SIN(RADIANS(2*M))
    c. Calculate the value of P3, with formula:
       P3 = -0,0392 x sin M’
       With Excel formula
       P3 =-0,0392*SIN(RADIANS(M’))
    d. Calculate the value of P4, with formula:
       P4 = 0,0116 x sin 2M’
       With Excel formula:
       P4 = =0,0116*SIN(RADIANS(2*M’))

---

[15] Pasaran is a term to describe the day of the week in Javanese society which consists of five days, namely: Legi, Pahing, Pon, Wage, Kliwon. Usually this market is associated with 7 names of the day of the week, such as Monday Pon, Friday Kliwon, etc.

[16] Ibn Ya’qub Al-Batawi, *Risalah Az-Zain,* 30.

e. Calculate the value of P5, with formula:
P5 = -0.0073 x E x sin M’+ M
With Excel formula:
P5 =-0,0073*E*SIN(RADIANS(M’+ M))

f. Calculate the value of P6, with formula:
P6 = +0.0067 x E x sin M’- M
With Excel formula:
P6 =0,0067*E*SIN(RADIANS(M’- M))

g. Calculate the value of P7, with formula:
P7 = +0.0118 x sin 2F
With Excel formula:
P7 =0,0118*SIN(RADIANS(2*F))

h. Calculate the value of P, with formula:
P = P1 + P2 + P3 + P4 + P5 + P6 + P7

32. Calculating the latitude of the month (Q), with the following corrections:

a. Calculate the value of Q1, with formula:
Q1 = -0.0048 x E x Cos M
With Excel formula:
Q1 =-0,0048*E*COS(RADIANS(M))

b. Calculate the value of Q2, with formula:
Q2 = +0.0020 x E x 2M
With Excel formula:
Q2 =0,002*E*COS(RADIANS(2*M))

c. Calculate the value of Q3, with formula:
Q3 = -0.3299 x M’
With Excel formula:
Q3 =-0,3299*COS(RADIANS(M’))

d. Calculate the value of Q4, with formula:

Q4 = -0.0060 x E x (M'+M)

With Excel formula:

Q4 =-0,006*E*COS(RADIANS(M'+M))

e. Calculate the value of Q5, with formula:

Q5 = +0.0041 x E x (M'–M)

With Excel formula:

Q5 =0,0041*E*COS(RADIANS(M'–M))

f. Calculate the value of Q, with formula:

Q = 5.2207 + Q1 + Q2 + Q3 +Q4 + Q5

With Excel formula:

Q =5,2207+SUM(First Data:Last Data)

The first data is the data in the first cell that we will add up, data in Q1

The last data is the data in the last cell that we will add up, data in Q5

Excel will immediately add up the data Q1, Q2, Q3, Q4, and Q5

33. Calculating the value of the magnitude of the month (U), with the following corrections:[17]

a. u1, with formula:

u1 = +0.0046 x E x Cos M

With Excel formula:

u1 =0,0046*E*COS(RADIANS(M))

b. Calculate the value of u2, with formula

u2 = –0.0182 x cos M'

With Excel formula:

u2 =-0,0182*COS(RADIANS(M'))

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[17] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain,* 31.

c. Calculate the value of u3, with formula:
   u3 = 0.0004 x cos 2M’
   With Excel formula:
   u3 =0,0004*COS(RADIANS(2*M’))
d. Calculate the value of u4, with formula:
   u4 = –0.0005 x cos (M+M’)
   With Excel formula:
   u4 =-0,0005*COS(RADIANS(M+M’))
e. Calculate the value of u, with formula:
   u = 0.0059 + u1 + u2 + u3 + u4
   With Excel formula:
   =0,0059+SUM(First Data:Last Data)
   The first data is the data in the first cell that we will add up, data in u1
   The last data is the data in the last cell that we will add up, data in u4
   Excel will immediately add up the data u1, u2, u3, and u4

34. Calculate the value of W, with formula:
    W = [cos F]
35. Calculate the value of Y, with formula:
    Y = (P Cos F+Q Sin F) x (1–0.0048 W)
36. Calculate the value of h, with formula:
    h = 1.5573 + u
37. Calculate the value of p, with formula:
    p = 1.0128 - u
38. Calculate the value of t, with formula:
    t = 0.4678 - u
39. Calculate the value of n, with formula:

n = 0.5458 + 0.0400 Cos M'

With Excel formula:

n =0,5458+0,04*COS(RADIANS(M’))

40. Calculating the Magnitude of the Eclipse, in the following way:

    a. Finding the Penumbra's Magnitude (MP), with formula:

       MP = (1.5573+u-[ϒ])/0.5450

    b. Finding the Umbra's Magnitude (MU), with formula:

    MU = (1.0128-u-[ϒ])/0.5450

The value of the eclipse magnitude will determine the type of lunar eclipse, with the following conditions:

- If the value of the magnitude of the umbra eclipse is positive and has a value of 1 and above, then a total lunar eclipse occurs.
- If the value of the magnitude of the umbra eclipse is positive and has a value of less than 1, then a partial lunar eclipse occurs.
- If the value of the magnitude of the umbra eclipse is negative and the result of the magnitude of the penumbra eclipse is positive, then a penumbra lunar eclipse occurs.
- If the value of the magnitude of the umbra eclipse is negative and the result of the magnitude of the eclipse is negative, there will be no eclipse.

41. Calculate the semi duration of the penumbra phase (TP), with formula:[18]

    $TP = \sqrt{(h^2-\Upsilon^2)}/n$

    With Excel formula:

    TP = SQRT(h^2-ϒ^2)/n

    Then change the result in the form of hours with Excel formula:

    TP=IF(TP<0;"-";)&TEXT(ABS(TP)/24;"[hh]:mm:ss")

42. Calculate the semi duration of the partial umbra phase (TU), with formula:

    $TU = \sqrt{(p^2-\Upsilon^2)}/n$

    With Excel formula:

    TU = SQRT(p^2-ϒ^2)/n

    Then change the result in the form of hours with Excel formula:

    TU=IF(TU<0;"";)&TEXT(ABS(TU)/24;"[hh]:mm:ss")

43. Calculate the semi duration of the total umbra phase (TT), with formula:

    $TT = \sqrt{(t^2-\Upsilon^2)}/n$

    With Excel formula:

    TT = SQRT(t^2-Y^2)/n

    Then change the result in the form of hours with Excel formula:

    TT=IF(TT<0;"";)&TEXT(ABS(TT)/24;"[hh]:mm:ss")

44. Determine the type of eclipse (TE), with Excel formula:

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[18] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain*, 32.

TE = IF (MP<0,"TG", IF ERROR (IF(TT>0,"T",""), IF(MU>0,"S","P")))

T= Total

S= Sebagian

P= Penumbra

With the following conditions:

a. If the MP value is less than 0, there will be no eclipse
b. If the TT value is bigger than 0, there will be a total lunar eclipse
c. If the MU value is bigger than 0, there will be a partial or penumbral eclipse

45. Calculating the Duration of the Penumbra Phase (DP), with formula:

DP = TP x 2

Then change the result in the form of hours with Excel formula:

DP in the form of hours =IF(DP<0;"-";)&TEXT(ABS(DP)/24;"[hh]:mm:ss")

46. Calculating the Duration of the Umbra Phase (DU), with formula:

DU = TU x 2

Then change the result in the form of hours with Excel formula:

DU in the form of hours =IF(DU<0;"-";)&TEXT(ABS(DU)/24;"[hh]:mm:ss")

47. Calculating the Duration of the Total Umbra Phase (DT), with formula:

DT = TT x 2

Then change the result in the form of hours with Excel formula:

DT in the form of hours = IF(DT<0;"-";)&TEXT(ABS(DT)/24;"[hh]:mm:ss")

Summarizing the Calculation of a Lunar Eclipse:[19]

1. Summarize the approximate time (month and year) of the occurrence of a lunar eclipse in the Hijri calendar.
   With Excel formula:
   Gerhana=CHOOSE(M;"Muharram";"Ṣafar";"Rabī'ulawwal";"Rabī'uṡṡānī";"Jumādalūlā";"Jumādalukhra";"Rajab";"Sya'ban";"Ramaḍan";"Syawwāl";"Żulqo'dah";"Żulhijjah")&" "&Y
2. Summing up the time (day, month, and year) of the lunar eclipse in the Gregorian Calendar.
   With Excel formula:
   Pada =IF(TE="TIDAK GERHANA";"";TGL&" "&CHOOSE(BLN;"Januari";"Februari";"Maret";"April";"Mei";"Juni";"Juli";"Agustus";"September";"Oktober";"November";"Desember";"Januari";"Februari")&" "&THN)
3. Summing up the days and pasaran for the lunar eclipse in the Gregorian Calendar.
   With Excel formula:
   =IF(TE="TIDAK GERHANA";"";IF(HA=0;"Sabtu";CHOOSE(HA;"Ahad";"Senin";"Selasa";"Rabu";"Kamis";"Jum'at"))&""&

[19] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain,* 34.

IF(Pa=0;"Kliwon";CHOOSE(Pa;"Legi";"Pahing";"Pon";"Wage")))

4. Summing up the timing of the initial contact of the lunar disc in the penumbra.
   With Excel formula:
   =IF(TE="TIDAK GERHANA";"";TEXT(IF(WD-TP<0;(WD-TP+24)/24;(WD-TP)/24);"[hh]:mm:ss"))
5. Summing up the timing of the initial contact of the lunar disc at the umbra.
   With Excel formula:
   =IF(TE="TIDAK GERHANA";"";IF(TE="Penumbra";"";TEXT(IF(WD-TU<0;(WD-TU+24)/24;(WD-TU)/24);"[hh]:mm:ss")))
6. Summing up the timing of the initial contact of the lunar disc in total eclipse.
   With Excel formula:
   =IF(TE="TIDAK GERHANA";"";IF(TE="Total";TEXT(IF(WD-TT<0;(WD-TT+24)/24;(WD-TT)/24);"[hh]:mm:ss");""))
7. Summing up the time of the greatest eclipse.
   With Excel formula:
   =IF(TE="TIDAK GERHANA";"";TEXT(WD/24;"[hh]:mm:ss"))
8. Summing up the time when the lunar disc contact ends in a total eclipse.[20]

[20] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain*, 35.

With Excel formula:

=IF(TE="TIDAK GERHANA";"";IF(TE="Total";TEXT(IF(WD+TT>24;(WD+TT-24);(WD+TT)/24);"[hh]:mm:ss");""))

9. Summing up the time when the lunar disk contact ends in the umbra.

   With Excel formula:

   =IF(TE="TIDAK GERHANA";"";IF(TE="Penumbra";"";TEXT(IF(WD+TU>24;(WD+TU-24)/24;(WD+TU)/24);"[hh]:mm:ss")))

10. Summing up the time when the lunar disk contact ends in the penumbra.

    With Excel formula:

    =IF(TE="TIDAK GERHANA";"";TEXT(IF(WD+TP>24;(WD+TP-24)/24;(WD+TP)/24);"[hh]:mm:ss"))

11. Summing up the value of gamma.

    With Excel formula:

    =IF(TE="TIDAK GERHANA";"";Y)

12. Summarize the value of the magnitude of the penumbra.

    With Excel formula:

    =IF(TE="TIDAK GERHANA";"";IF(MP>0;MP;""))

13. Summing up the value of umbra magnitude.

    With Excel formula:

    =IF(TE="TIDAK GERHANA";"";IF(MU>0;MU;""))

14. Summing up the type of eclipse (JG)

    With Excel formula:

= TE

15. Summing up the duration of the penumbra.
 With Excel formula:
 =IF(TE="TIDAK GERHANA";"";DP)
16. Summing up the umbra duration.
 With Excel formula:
 =IF(TE="TIDAK GERHANA";"";IF(JG ="Penumbra";"";DU))
17. Summing up the total duration.
 With Excel formula:
 =IF(TE="TIDAK GERHANA";"";IF(JG="Total";DT;""))

D. Example of Calculating of Lunar Eclipse in The Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

The following is an example of calculating a lunar eclipse in the book *Risālah az-Zain* which is expected to occur in the month of Shawwal in 1442 AH:[21]

1. Estimated year and month of the lunar eclipse
 Hijri Year (Y) : 1442
 Hijri Month (M) : 10 (Syawwal)
2. Time Zone (TZ) : 7 (WIB)
 Adjusts the observer position when doing calculations.
3. Estimated year (Y) = year + (months that have passed / 12)

[21] Ibn Ya'qub Al-Batawi, *Risalah Az-Zain,* 37.

$Y = 1442 + (10/12)$

$Y = 1442{,}83$

4. Calculate the value of K

   $K = (Y – 1420{,}75) \times 12 – 0{,}5$

   $K = (1442{,}83 – 1420{,}75) \times 12 – 0{,}5$

   $K = 264{,}50$

5. Calculate the value of T

   $T = K / 1236{,}85$

   $T = 264{,}50 / 1236{,}85$

   $T = 0{,}213850$

6. Calculate the value of JDE

   $JDE = 2451550{,}09766 + 29{,}530588861 \times k + 0{,}00015437 \times T^2 - 0{,}00000015 \times T^3 + 0{,}00000000073 \times T^4$

   $JDE = 2451550{,}09766 + 29{,}530588861 \times 264{,}50 + 0{,}00015437 \times 0{,}213850^2 - 0{,}00000015 \times 0{,}213850^3 + 0{,}00000000073 \times 0{,}213850^4$

   $JDE = 2459360{,}938421$

7. Calculate the value of M

   $M = 2{,}5534 + 29{,}1053567 \times K – 0{,}0000014 \times T^2 - 0{,}00000011 \times T^3$

   $M = 2{,}5534 + 29{,}1053567 \times 264{,}50 – 0{,}0000014 \times 0{,}213850^2 - 0{,}00000011 \times 0{,}213850^3$

   $M = 140{,}\ 920247$

8. Calculate the value of M’

   $M’ = 201{,}5643 + 385{,}81693528 \times K + 0{,}0107582 \times T^2 +0{,}00001238 \times T^3 - 0{,}000000058 \times T^4$

M’ = 201,5643 + 385,81693528 x 264,50 + 0,0107582 x $0,213850^2$ +0,00001238 x $0,213850^3$ - 0,000000058 x $0,213850^4$

M’ = 10, 144174

9. Calculate the value of Ω

Ω = 124,7746 – 1,56375588 x K+ 0,0020672 x T^2 + 0,00000215 x T^3

Ω = 124,7746 – 1,56375588 x 264,50 + 0,0020672 x $0,213850^2$ +0,00000215x$0,213850^3$

Ω = 71, 161264

10. Calculate the value of F

F = 160,7108 + 390,67050284 x K – 0,0016118 x T^2 - 0,00000227 x T^3 + 0,000000011 x T^4 – 0,026665 x sin Ω

F = 160,7108 + 390,67050284 x 264,50 – 0,0016118 x $0,213850^2$ - 0,00000227 x $0,213850^3$ + 0,000000011 x $0,213850^4$ – 0,026665 x sin 71, 161264

F = 173, 033505

11. Determine the probability of an eclipse

Imkan = IF (ABS(SIN(RADIANS(F))) < 0,3588, “M”, “T”)

Imkan = IF (ABS(SIN(RADIANS(173, 033505))) < 0,3588, “M”, “T”)

Imkan = 0,1213 (Potential)

12. Calculate the value of E

E = 1 – 0,002561 x T – 0,0000074 x T^2

E = 1 – 0,002561 x 0,213850 – 0,0000074 x $0,213850^2$

E = 0, 999462

13. Calculate the value of A

    A = 0,0003 x sin (299,77 + 0,107408 x K – 0,009173 x T^2)

    A = 0,0003 * SIN(RADIANS(299,77 + 0,107408 * K – 0,009173 x T^2))

    A = 0,0003 * SIN(RADIANS(299,77 + 0,107408 * 264,50 – 0,009173 x $0,213850^2$))

    A = -0,000158

14. Calculate the value of C
    a. Calculate the value of C1

       C1= -0,4065*SIN(RADIANS(M’))

       C1= -0,4065*SIN(RADIANS(10,144174))

       C1= -0,071595
    b. Calculate the value of C2

       C2= 0,1727*E* SIN(RADIANS(M))

       C2=0,1727*0,999462*SIN(RADIANS(140,920247))

       C2= 0,108812
    c. Calculate the value of C3

       C3= 0,0161*SIN(RADIANS(2*M’))

       C3= 0,0161*SIN(RADIANS(2*10,144174))

       C3= 0,005583
    d. Calculate the value of C4

       C4= 0,0097*SIN(RADIANS(2*F))

       C4= 0,0097*SIN(RADIANS(2*173,033505))

       C4= 0,002336
    e. Calculate the value of C5

       C5= 0,0073*E*SIN(RADIANS(M’-M))

C5=0,0073*0,999462*SIN(RADIANS(10,144174-140,920247))

C5= -0,005525

f. Calculate the value of C6

C6= -0,0050*E*SIN(RADIANS(M'+M))

C6=-0,0050*0,999462*SIN(RADIANS(10,144174-40,920247))

C6= -0,002418

g. Calculate the value of C7

C7= -0,0023*SIN(RADIANS(M'-2*F))

C7= -0,0023*SIN(RADIANS(10,144174-2*173,033505))

C7= -0,000938

h. Calculate the value of C8

C8= 0,0021 * E * SIN(RADIANS(2*M))

C8=0,0021*0,999462*SIN(RADIANS(2*140,920247))

C8= -0,002054

i. Calculate the value of C9

C9= 0,0012 * SIN(RADIANS(M'+2*F))

C9=0,0012*SIN(RADIANS(10,144174+2*173,033505))

C9 -0,000079

j. Calculate the value of C10

C10= 0,0006 * E * SIN(RADIANS(2*M'+M)

C10=0,0006*0,999462*SIN(RADIANS(2*10,144174+140,920247)

C10= 0,000193

k. Calculate the value of C11

C11 = -0,0004 * SIN(RADIANS(3*M'))

C11 = -0,0004 * SIN(RADIANS(3*10,144174))

C11 = -0,000203

l. Calculate the value of C12

C12 = -0,0003 * E * SIN(RADIANS(M+2*F))

C12 = -0,0003 * 0,999462 * SIN(RADIANS(140,920247+2*173,033505))

C12 = -0,000240

m. Calculate the value of C13

C13 = -0,0002 *E * SIN(RADIANS(M-2*F))

C13 = -0,0002 * 0,999462 * SIN(RADIANS(140,920247-2*173,033505))

C13 = -0,000085

n. Calculate the value of C14

C14 = -0,0002 * E * SIN(RADIANS(2*M'-M))

C14 = -0,0002 * 0,999462 * SIN(RADIANS(2*10,144174-140,920247))

C14 = 0,000172

o. Calculate the value of C15

C15 = -0,0002 * SIN(RADIANS(Ω))

C15 = -0,0002 * SIN(RADIANS(71,161264))

C15 = -0,000189

p. Calculate the value of C

C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 + C12 + C13 + C14 + C15

C =SUM (First Data:Last Data)

C = 0,033769

15. Calculate the value of JDE TE

JDE TD = JDE + A + C + 0,5

JDE TD = 2459360,938421 + -0,000158 + 0,033769 + 0,5

JDE TD = 2459361,472032

16. Calculate the value of JDE WD

JDE WD = JDE TD + TZ / 24

JDE WD = 2459361,472032 + 7 / 24

JDE WD = 2459361,763698

17. Calculate the value of GMT

GMT = (JDE TD - INT(JDE TD))*24

GMT = (2459361,472032 - INT(2459361,472032)) *24

GMT = 11,328758

18. Calculate the value of WD

WD = (JDE WD - INT(JDE WD))*24

WD = (2459361,763698- INT(2459361,763698)) *24

WD = 18,328758

19. Calculate the value of Z

Z = INT(JDE WD)

Z = INT(2459361,763698)

Z = 2459361

20. Calculate the value of α

α = INT((Z- 1867216,25) / 36524,25)

α = INT((2459361- 1867216,25) / 36524,25)

α = 16

21. Calculate the value of A

    A = IF(Z<2299161;Z;Z+1+ α -INT(α /4))

    A = IF(2459361<2299161; 2459361; 2459361+1+ 16 -INT(16 /4))

    A = 2459374

22. Calculate the value of B

    B = A + 1524

    B = 2459374 + 1524

    B = 2460898

23. Calculate the value of C

    C = INT((B - 122,1) / 365,25)

    C = INT((2460898 - 122,1) / 365,25)

    C = 6737

24. Calculate the value of D

    D = INT(365,25 *C)

    D = INT(365,25 *6737)

    D = 2460689

25. Calculate the value of E

    E = INT((B -D) / 30,6001)

    E = INT((2460898 -2460689) / 30,6001)

    E = 6

26. Determine the date of the lunar eclipse

    TGL =B-D-INT(30,6001*E)

    TGL =2460898 -2460689-INT(30,6001*6)

    TGL =26

27. Determine the month of the lunar eclipse

    BLN =IF(E>=14;E-13;E-1)

    BLN =IF(6>=14;6-13;6-1)

    BLN =5

28. Determine the year of the lunar eclipse

    THN =IF(BLN<=2;C-4715;C-4716)

    THN =IF(5<=2;6737-4715;6737-4716)

    THN =2021

29. Calculate the value of HA

    HA =MOD(Z+2;7)

    HA =MOD(2459361+2;7)

    HA =4

30. Calculate the value of Pa

    Pa =MOD(Z+1;5)

    Pa =MOD(2459361+1;5)

    Pa = 2

31. Calculate the value of P

    a. Calculate the value of P1

        P1 =0,207*E*SIN(RADIANS(M))

        P1=0,207*0,999462*SIN(RADIANS(140,920247)

        P1 =0,130423

    b. Calculate the value of P2

        P2 =0,0024*E*SIN(RADIANS(2*M))

        P2 =0,0024*0,999462*SIN(RADIANS(2*140,920247))

        P2 =-0,002348

    c. Calculate the value of P3

        P3 =-0,0392*SIN(RADIANS(M'))

        P3 =-0,0392*SIN(RADIANS(10,144174))

        P3 =-0,006904

    d. Calculate the value of P4

P4 = 0,0116*SIN(RADIANS(2*M’))

P4 = 0,0116*SIN(RADIANS(2*10,144174))

P4 =0,004022

e. Calculate the value of P5

P5 =-0,0073*E*SIN(RADIANS(M’+ M))

P5 = 0,0073*0,999462*SIN(RADIANS(10,144174+ 140,920247))

P5 =-0,003530

f. Calculate the value of P6

P6 =0,0067*E*SIN(RADIANS(M’- M))

P6 =0,0067*0,999462*SIN(RADIANS(10,144174- 140,920247))

P6 =-0,005071

g. Calculate the value of P7

P7 =0,0118*SIN(RADIANS(2*F))

P7 =0,0118*SIN(RADIANS(2*F))

P7 =-0,002841

h. Calculate the value of P

P = SUM(P1:P7)

P = SUM(First Data:Last Data)

P = 0,113751

32. Calculate the value of Q

a. Calculate the value of Q1

Q1 =-0,0048*E*COS(RADIANS(M))

Q1=-0,0048*0,999462*COS(RADIANS(140,920247))

Q1 =0,003724

b. Calculate the value of Q2

Q2 =0,002*E*COS(RADIANS(2*M))

Q2=0,002*0,999462*COS(RADIANS(2*140, 920247))

Q2 =0,000410

c. Calculate the value of Q3

Q3 =-0,3299*COS(RADIANS(M'))

Q3 =-0,3299*COS(RADIANS(10,144174))

Q3 = -0,324743

d. Calculate the value of Q4

Q4 =-0,006*E*COS(RADIANS(M'+M))

Q4 =-0,006*0,999462*COS(RADIANS(10,144174+140,920247))

Q4 =0,005248

e. Calculate the value of Q5

Q5 =0,0041*E*COS(RADIANS(M'–M))

Q5 =0,0041*0,999462*COS(RADIANS(10,144174–140,920247))

Q5 =-0,002676

f. Calculate the value of Q

Q =5,2207+SUM(Q1:Q5)

Q =5,2207+SUM(Q1:Q5)

Q = 4,902663

33. Calculating the value of the magnitude of the month, with the following corrections:

a. Calculate the value of u1

u1 =0,0046*E*COS(RADIANS(M))

u1=0,0046*0,999462*COS(RADIANS(140,9 20247))

u1 =-0,003569

b. Calculate the value of u2,

u2 =-0,0182*COS(RADIANS(M'))

u2 =-0,0182*COS(RADIANS(10,144174))

u2 =-0,017915

c. Calculate the value of u3

u3 =0,0004*COS(RADIANS(2*M'))

u3 =0,0004*COS(RADIANS(2*10,144174))

u3 =0,000375

d. Calculate the value of u4

u4 =-0,0005*COS(RADIANS(M+M'))

u4=-0,0005*COS(RADIANS(140,920247+10,144174))

u4 =0,000438

e. Calculate the value of u

u =0,0059+SUM(u1:u4)

u =0,0059+SUM(u1:u4)

u =-0,014772

34. Calculate the value of W

W = [cos F]

W =ABS(COS(RADIANS(173,033505)))

W = 0,9926

35. Calculate the value of Y

Y = (P Cos F+Q Sin F) x (1–0.0048 W)

Y =(0,113751*COS(RADIANS(0,9926))+ 4,902663*SIN(RADIANS(0,9926)))*(1-0,0048*0,9926)

Y = 0,4794

36. Calculate the value of h

    h = 1.5573 + u

    h = 1.5573 + -0,014772

    h = 1,542528

37. Calculate the value of p

    p = 1.0128 – u

    p = 1.0128 – -0,014772

    p = 1,027572

38. Calculate the value of t

    t = 0.4678 – u

    t = 0.4678 – -0,014772

    t = 0,482572

39. Calculate the value of n

    n =0,5458+0,04*COS(RADIANS(M'))

    n =0,5458+0,04*COS(RADIANS(10,144174))

    n =0,585175

40. Calculating the Magnitude of the Eclipse
    a. Calculate the value of MP

       MP = (1.5573+u-[ϒ])/0.5450

       MP = (1.5573+-0,014772-[0,4794])/0.5450

       MP = 1,9506

    b. Calculate the value of MU

       MU = (1.0128-u-[ϒ])/0.5450

       MU = (1.0128--0,014772-[0,4794])/0.5450

       MU = 1,0058

41. Calculate the value of TP

TP = SQRT(h^2-ϒ^2)/n

TP = SQRT(1,542528^2-0,4794^2)/ 0,585175

TP = 2,505458

Then change the result in the form of hours with Excel formula:

TP =IF(TP<0;"-";)&TEXT(ABS(TP)/24;"[hh]:mm:ss")

TP =IF(TP<0;"-";)&TEXT(ABS(2,505458)/24;"[hh]:mm:ss")

TP =02:30:20

42. Calculate the value of TU

TU = SQRT(p^2-ϒ^2)/n

TU = SQRT(1,027572^2-0,4794^2)/0,585175

TU =1,553163

Then change the result in the form of hours with Excel formula:

TU =IF(TU<0;"-";)&TEXT(ABS(TU)/24;"[hh]:mm:ss")

TU =01:33:11

43. Calculate the value of TT

TT = SQRT(t^2-Y^2)/n

TT = SQRT(0,482572^2-0,4794^2)/0,585175

TT =0,093914

Then change the result in the form of hours with Excel formula:

TT =IF(TT<0;"-";)&TEXT(ABS(TT)/24;"[hh]:mm:ss")

TT =00:05:38

44. Calculate the value of TE

TE = IF (MP<0,"TG", IF ERROR (IF(TT>0,"T",""), IF(MU>0,"S","P")))

TE = Total

45. Calculate the value of DP

DP = TP x 2

DP = 2,505458 x 2

DP = 5,010915

Then change the result in the form of hours with Excel formula:

DP =IF(DP<0;"-";)&TEXT(ABS(DP)/24;"[hh]:mm:ss")

DP =05:00:39

46. Calculate the value of DU

DU = TU x 2

DU = 1,553163 x 2

DU = 3,106327

Then change the result in the form of hours with Excel formula:

DU =IF(DU<0;"-";)&TEXT(ABS(DU)/24;"[hh]:mm:ss")

DU =03:06:23

47. Calculate the value of DT

DT = TT x 2

DT = 0,093914 x 2

DT = 0,187827

Then change the result in the form of hours with Excel formula:

DT = IF(DT<0;"-";)&TEXT(ABS(DT)/24;"[hh]:mm:ss")

DT = 00:11:16

Summarizing the Calculation of a Lunar Eclipse:

1. Lunar Calendar Date

   Gerhana=CHOOSE(M;"Muharram"; "Ṣafar";"Rabī’ulawwal";"Rabī’uṡṡānī"; "Jumādalūlā"; "Jumādalukhra"; "Rajab";"Sya'ban"; "Ramaḍan"; "Syawwāl"; "Żulqo’dah"; "Żulhijjah")&" "&Y

   Gerhana =Syawwāl 1442 H

2. Gregorian Date

   Pada=IF(TE="TIDAK GERHANA";"";TGL&" "&CHOOSE(BLN;"Januari"; "Februari";"Maret";"April";"Mei";"Juni";"Juli";"Agustus";"September";"Oktober";"November";"Desember";"Januari";"Februari")&" "&THN)

   Pada = 26 Mei 2021 M

3. Day and Pasaran

   Hari=IF(TE="TIDAK GERHANA";"";IF(HA=0;"Sabtu";CHOOSE(HA;"Ahad";"Senin";"Selasa";"Rabu";"Kamis";"Jum'at"))&" "&IF(Pa=0;"Kliwon";CHOOSE(Pa;"Legi";"Pahing";"Pon";"Wage")))

   Hari = Rabu Pahing

4. Initial Contact of The Lunar Disc in The Penumbra

   Awal Penumbra =IF(TE="TIDAK GERHANA";"";TEXT(IF(WD-TP<0;(WD-TP+24)/24;(WD-TP)/24);"[hh]:mm:ss"))

Awal Penumbra = 15:49:24

5. Initial Contact of The Lunar Disc in The Umbra

Awal Umbra =IF(TE="TIDAK GERHANA";"";IF(TE="Penumbra";"";TEXT(IF(WD-TU<0;(WD-TU+24)/24;(WD-TU)/24);"[hh]:mm:ss")))

Awal Umbra = 16:46:32

6. Initial Contact of The Lunar Disc in Total Eclipse

Awal Total =IF(TE="TIDAK GERHANA";"";IF(TE="Total";TEXT(IF(WD-TT<0;(WD-TT+24)/24;(WD-TT)/24);"[hh]:mm:ss");""))

Awal Total = 18:14:05

7. The Greatest Eclipse

Puncak Gerhana =IF(TE="TIDAK GERHANA";"";TEXT(WD/24;"[hh]:mm:ss"))

Puncak Gerhana = 18:19:44

8. End of Total Eclipse

Akhir Total =IF(TE="TIDAK GERHANA";"";IF(TE="Total";TEXT(IF(WD+TT>24;(WD+TT-24);(WD+TT)/24);"[hh]:mm:ss");""))

Akhir Total = 18:25:22

9. End of Umbra Eclipse

Akhir Umbra =IF(TE="TIDAK GERHANA";"";IF(TE="Penumbra";"";TEXT(IF(WD+TU>24;(WD+TU-24)/24;(WD+TU)/24);"[hh]:mm:ss")))

Akhir Umbra = 19:52:55

10. End of Penumbra Eclipse

Akhir Penumbra =IF(TE="TIDAK GERHANA";"";TEXT(IF(WD+TP>24;(WD+TP-24)/24;(WD+TP)/24);"[hh]:mm:ss"))

Akhir Penumbra = 20:50:03

11. Gamma =IF(TE="TIDAK GERHANA";"";Y)

    Gamma = 0.4794

12. Penumbra Magnitude

    Magnitudo Penumbra =IF(TE="TIDAK GERHANA";"";IF(MP>0;MP;""))

    Magnitudo Penumbra = 1.9506

13. Umbra Magnitude

    Magnitudo Umbra =IF(TE="TIDAK GERHANA";"";IF(MU>0;MU;""))

    Magnitudo Umbra =1.0058

14. Type of Eclipse = TE

    Jenis Gerhana = Gerhana Bulan Total

15. Duration of Penumbra

    Durasi Penumbra =IF(TE="TIDAK GERHANA";"";DP)

    Durasi Penumbra = 05:00:39

16. Duration of Umbra

    Durasi Umbra =IF(TE="TIDAK GERHANA";"";IF(JG ="Penumbra";"";DU))

    Durasi Umbra= 03:06:23

17. Duration of Total Eclipse

    Durasi Total =IF(TE="TIDAK GERHANA";"";IF(JG="Total";DT;""))

    Durasi Total = 00:11:16

CONCLUSION[22]	
Lunar Calendar Date	Syawwal 1442 H
Grego Calendar Date	26 May 2021 M
Day and *Pasaran*	Thursday Pahing
Start of Penumbra Eclipse	15:49:24
Start of Umbra Eclipse	16:46:32
Start of Total Eclipse	18:14:05
Greatest Eclipse	18:19:44
End of Total Eclipse	18:25:22
End of Umbra Eclipse	19:52:55
End of Penumbra Eclipse	20:50:03
Gamma	0.4794
Penumbra Magnitude	1.9506
Umbra Magnitude	1.0058
Eclipse Type	Total
Durasi of Penumbra	05:00:39
Duration of Umbra	03:06:23
Duration of Total Eclipse	00:11:16

Table 3.3 Conclusion of Risālah az-Zain's Calculation

[22] *Ibid.*

CHAPTER IV
THE ALGORITHM ANALYSIS OF THE LUNAR ECLIPSE CALCULATION IN THE BOOK *RISĀLAH AZ-ZAIN* BY IBN YA'QŪB AL-BATĀWY

A. Algorithm Analysis of the Lunar Eclipse Calculation in the Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

In calculating lunar eclipses, we can see that there are differences in determining when an eclipse will occur. The calculation method in Indonesia according to the system can be divided into two major groups, namely *hisāb 'urfi* and *hisāb haqīqī*. However, time by time, new calculation methods produced more new accurate calculations, such as *hisāb haqiqi bi at-taqrib*, *hisāb haqiqi bi at-tahqiq* and *hisāb haqiqi contemporary*.[1]

Calculation methods will continue to evolve over time. One of the factors that have a big influence is the development of technology. The calculation method data will continue to change because it is dynamic.[2] The growth of Falak Science at this time is very advanced. It has even reached a high level of accuracy and is almost perfect so that the possibility of error is relatively little.[3]

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[1] Ichtijanto, dkk, *Almanak Hisab Rukyat*, Jakarta: Proyek Pembinaan Badan Peradilan Agama Islam, 1981, 37-38.

[2] Sukarni, "Metode Hisab Gerhana Bulan Ahmad Ghozali", 73.

[3] A. Kadir, *Formula Baru Ilmu Falak*, 5.

In determining the calculation of lunar eclipses, there are several methods that can be used, one of which is *hisāb haqiqi contemporary* which has a high level of accuracy because it is based on astronomical calculations. Basically, *hisāb haqiqi contemporary* is similar to *hisāb haqiqi bi at-tahqiq*, which is the calculation based on astronomical data that has been processed with spherical trigonometry with various corrections made to the calculation of the motion of the Moon and the Sun with great accuracy. Meanwhile, the difference between *hisāb haqiqi contemporary* and *hisāb haqiqi bi at-tahqiq* is the presented data. These data are ready-made data and just need to be applied in the spherical triangle formula, without having to be processed as before. In addition, the corrections made in *hisāb haqiqi contemporary* are quite numerous.[4]

There are many programs, software, or others that only display data as material in *hisāb haqiqi contemporary* calculations, including: Nautical Almanac, Astronomical Almanac, Jean Meeus, EW. Brown, New Comb, Ephemeris *Hisāb Rukyat*, (Hisab Win and Win Hisab), Ephemeris *al-Falakiyah*, *Taqwīm al-Falakiyah*, *Mawāqīt*, *Nūr al-Falak*, *Nūr al-Anwār* Program, *al-Ahillah*, Mooncal Monzur, Accurate Times, Sun Times, Ascript, and so on.[5]

Nowadays, there are more and more astronomical software programs for the Moon and the Sun for the purposes of calculating the Qibla direction, prayer times, the beginning of the Moon and the eclipse. Such programs

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[4] Hanik Maridah, "Studi Analisis Hisab Gerhana Bulan", 80.
[5] Rifa Jamaludin Nasir, *Pemikiran Hisab,* 41.

include the *Mawāqīt* program programmed by the Dutch Korwil IMCI in 1993, the *Falakiyah Najmi* program by Nuril Fu'ad in 1995, the *Astinfo* program by the astronomy department of MIPA ITB Bandung in 1996, the *Badi'atul Mitsal* program in 2000 and the *Ahillah* program, *Misal*, *Pengetan* and *Tsaqib* in 2004 by Muhyiddin Khazin, *Mawāqīt* program 2002 version by Ing Khafid in 2002.[6]

The *Risālah az-Zain* book is a book written by Ibn Ya'qūb al-Batāwy. This book was compiled in 2020 which discusses the phases of the moon, the movement of the Moon, the movement of the Sun, determining the beginning of the month of the Hijri Calendar, solar eclipses, and lunar eclipses. For the calculation of lunar eclipses, Ibn Ya'qūb al-Batāwy referred to Jean Meeus' lunar eclipse algorithm then made some changes to the formula.

1. The theory used in the Book *Risālah az-Zain*

   The algorithm for calculating the lunar eclipse in the book Risalah Az-Zain is one of the *hisāb haqiqi contemporary*, the most accurate calculation compared to the *hisāb haqiqi bi at-taqrib* and *hisāb haqiqi bi at-tahqiq*. Ibn Ya'qūb al-Batāwy included the lunar eclipse reckoning algorithm in the Microsoft Excel program. The program contains the reckoning of solar and lunar eclipses. The eclipse calculation algorithm in this book refers to Jean Meeuss' lunar eclipse calculation algorithm which uses the latest theor; the reduction of the Moon from Chapront ELP-2000/82 and the Sun

[6] Muhyiddin Khazin, *Ilmu Falak dalam Teori dan Praktek*, 37.

using the reduction of Betragon-Francous VSOP87 which has high accuracy.

2. Source of data used in the Book *Risālah az-Zain*

The lunar eclipse calculation algorithm used in *Risālah az-Zain* is based on Jean Meeus' Astronomical Algorithms. [7] In this book, Jean Meeus uses Julian Day to calculate lunar eclipses. Julian Day is defined as the number of days that have passed since Monday January 1, 4713 BC at midday or 12:00:00 GMT[8] and uses the new epoch standard 2000.[9]

Jean Meeus uses the Danjon rules in his book. [10] This rule has been used since 1951 by the French Almanac, Connaissance des on the earth's image by increasing the earth's diameter by 1/85. Danjon's method differs from Chauvenet's rule which determines the effect of the Earth's atmosphere on the Earth's shadow with an elongation of 1/50 on the diameter of the umbra and penumbra shadows.

This rule has been used by many state institutions to predict lunar eclipses for a long time since 1891. This Chauvenet rule is commonly called the traditional rule. NASA chose to use the danjon rule rather than the traditional rule in *Eclipses During 2007* which is a data collection of solar and lunar eclipses throughout 2007.

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[7] Interview with Ibn Ya'qūb al-Batāwy via WhatsApp on December 22, 2020 at 09.58 WIB

[8] Jean Meeus, *Astronomical Algorithm,* (Virginia: Willman Bell. Inc., 1991), 1.

[9] Jean Meeus, *Astronomical Algorithms*, 1

[10] Jean Meeus, *Astronomical Algorithms*, 383.

When compared to the Danjon rule and traditional rules in calculating the magnitude of the lunar eclipse, the result of the magnitude calculation using the traditional rule is 0.005 for the umbral eclipse and 0.026 for the penumbral eclipse compared to the result of the magnitude calculation according to the Danjon rule.[11]

So, there are several eclipses that approach the boundary of partial and penumbra eclipses or between partial and total eclipses where the classification of eclipse types can differ between those using the Danjon rule and the traditional rules because in determining the type of eclipse using the magnitude calculation result.[12]

There are several differences between Ibn Ya'qub Al-Batawi's lunar eclipse reckoning algorithm and Jean Meeus, such as: calculating the value of K (estimated year of the eclipse), simplification of the formula F (argument for the latitude of the Moon), formula for calculating the value of A (additional correction to get the value of C), correction formula to determine the value of C (time of maximum eclipse), determination of *Pasaran* when the eclipse occurs

The following is a difference of Jean Meeus' lunar eclipse reckoning algorithm with Ibn Ya'qub Al-Batawi:

Jean Meeus	Ibn Ya’qub Al-Batawi
K= INT(year + (months	K = (year + (months that

[11] Alamul Yaqin, “Algoritme Hisab Gerhana Bulan Menurut Rinto Anugraha”, 100.

[12] *Ibid.*

that have passed/12)-2000)x 12,3685	have passed/12) – 1420,75) x 12 – 0,5
F = 160,7108 + 390,67050284 x K – 0,0016118 x T^2 - 0,00000227 x T^3 + 0,000000011 x T^4	F = 160,7108 + 390,67050284 x K – 0,0016118 x T^2 - 0,00000227 x T^3 + 0,000000011 x T^4 – 0,026665 x sin Ω
F_1 = F – 0,02665 x sin Ω	-
A_1 = 299,77 + 0,107408 x K – 0,009173 x T^2	A = 0,0003 x sin (299,77 + 0,107408 x K – 0,009173 x T^2)
C1 = -0,4065 x sin M’ C2 = 0,1727 x E x sin M C3 = 0,0161 x sin 2M’ C4 = 0,0097 x sin $2F_1$ C5 = 0,0073 x E x sin (M’-M) C6 = -0,0050 x E x sin (M’+M) C7 = -0,0023 x sin (M’-$2F_1$) C8 = 0,0021 x E x sin 2M C9 = 0,0012 x sin (M’+$2F_1$) C10 = 0,0006 x E x sin (2M’+M) C11 = -0,0004 x sin 3M’ C12 = -0,0003 x E x sin (M+$2F_1$) C 13 = 0,0003 x sin A_1 C14 = -0,0002 x E x sin (M-$2F_1$) C15 = -0,0002 x E x sin (2M’-M) C16 = -0,0002 x sin Ω	C1 = -0,4065 x sin M’ C2 = 0,1727 x E x sin M C3 = 0,0161 x sin 2M’ C4 = 0,0097 x sin 2F C5 = 0,0073 x E x sin (M’-M) C6 = -0,0050 x E x sin (M’+M) C7 = -0,0023 x sin (M’-2F) C8 = 0,0021 x E x sin 2M C9 = 0,0012 x sin (M’+2F) C10 = 0,0006 x E x sin (2M’+M) C11 = -0,0004 x sin 3M’ C12 = -0,0003 x E x sin (M+2F) * C13 = -0,0002 x E x sin (M-2F) C14 = -0,0002 x E x sin (2M’-M) C15 = -0,0002 x sin Ω

-	Pasaran =MOD(Z+1;5)

Table 4.1 Formula Difference of Jean Meeus and Ibn Ya'qub Al-Batawi

From the table above shows that there is a difference in determining the value of K. Jean Meeus using the Gregorian calendar as the basis for calculations while Ibn Ya'qūb al-Batāwy uses the Hijri calendar. This change is due to the adjustment of Islamic boarding school education which uses the *Hijriyah* calendar as the academic calendar.[13] This book also targets students and beginners who are just learning about calculation and to make it easier for them to understand calculations.[14]

Unlike Jean Meeus who used the F_1 formula, Ibn Ya'qūb al-Batāwy simplified the formula by entering the F_1 formula into the F formula and eliminating F_1 calculations, thus indirectly affecting other formulas that required the value of F. Ibn Ya'qūb al-Batāwy also moved Jean Meeus's correction formula C13 to formula A, so that the correction value of C in the book Risālah az-Zain only amounts to 15, less than one correction from Jean Meeus's calculation of 16.

Influenced by the geography in which this book was written, on the island of Java, Indonesia, Ibn Ya'qūb al-Batāwy included calculations in determining the *Pasaran* at the time of the eclipse. The market is a week of five days: *Legi, Pahing, Pon, Wage,* and *Kliwon. Pasaran* is a day rule commonly used by the people of Java and its surroundings.[15]

In determining the time of the eclipse, the value of Delta T is needed. The value of Delta T is the time difference between TD (Dynamical Time) and UT (Universal Time). Please note, the basis for measuring time is the earth's

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[13] Interview with Ibn Ya'qūb al-Batāwy via WhatsApp on May, 7 2021 at 11.00 WIB.

[14] Interview with Ibn Ya'qūb al-Batāwy via WhatsApp on May, 25 2021 at 13.58 WIB.

[15] *Ibid.*

rotation about its axis, but the Earth's rotation is not constant over time because of its increasingly slow and irregular motion.[16] Therefore, the Delta T value is needed to produce a more accurate and precise calculation. Considering that this book is targeted at beginners, Ibn Ya'qūb al-Batāwy does not use the Delta T formula.[17] However, the deletion of the Delta T formula does not have a significant effect on the results of the calculation.

B. Analysis Accuracy of Lunar Eclipse Calculation in the Book *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

As time progressed, astronomy calculations had higher accuracy. This is why accuracy problems for books that are classified as newly published are important. Books that have high accuracy will become references by students or the people who study them. The existence of this book must be maintained because it will become an important reference needed in terms of worship and also enrich the treasures of knowledge, especially in the field of astronomy.

The author tested the accuracy of Ibn Ya'qub al-Batawi's lunar eclipse reckoning algorithm with 2 lunar eclipse reckoning data. *First*, the data calculated by Jean Meeus contained in the *Astronomical Algorithm* book because the algorithm of the *Risālah az-Zain* book is sourced from the *Astronomical Algorithm* book with several differences such as simplification of certain formulas, omitting some calculations, and adding formulas. *Second*, data from NASA (National Aeronautics and Space

[16] Rinto Anugraha, "Macam-Macam Waktu", (tt: tp, tth), not published.
[17] Interview with Ibn Ya'qūb al-Batāwy via WhatsApp on May, 25 2021 at 13.58 WIB.

Administration) calculations. A most credible institution where the calculations are the most precise and become a reference for research related to outer space.

The following is calculation results of the Algorithm for calculating the lunar eclipse according to Ibn Ya'qūb al-Batāwy in the book *Risālah az-Zain* with the 2 data reckoning the lunar eclipse that has been mentioned before which are grouped based on each phase of the eclipse time:

1. Jean Meeus and Ibn Ya'qūb al-Batāwy

The author calculates the lunar eclipse of Ibn Ya'qūb al-Batāwy using a Microsoft excel-based method as written in the book *Risālah az-Zain* and tested the accuracy of its book with Jean Meeus' calculations and entered into Microsoft Excel and added NASA's delta T polynomial formula and made changes such as which the authors include in table 4.1. The addition of the NASA delta T formula is necessary because the delta T data in the Astronomical Algorithm book only includes observational data from 1620 to 1992, so to get the desired results for the year after 1992, NASA's delta T needs to be inserted.

The author used data of 30 lunar eclipses from 2021-2034 (13 years), with details; 13 total lunar eclipses, 8 partial lunar eclipses, and 9 penumbral lunar eclipses, as follows:

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb	Difference in Value

				al-Batāwy	(Jean Meeus - Ibn Ya'qūb al-Batāwy)
			First Contact with the Penumbra (UT)		
1.	26 May 2021	T	8:48:12	08:49:24	-0:01:12
2.	19 November 2021	P	6:04:03	06:05:15	-0:01:12
3.	16 May 2022	T	1:32:20	01:33:33	-0:01:13
4.	8 November 2022	T	8:03:13	08:04:27	-0:01:14
5.	5 May 2023	N	15:15:09	15:16:23	-0:01:14
6.	28 October 2023	P	18:02:36	18:03:50	-0:01:14
7.	25 March 2024	N	4:54:43	04:55:57	-0:01:14
8.	18 September 2024	P	0:42:27	00:43:41	-0:01:14
9.	14 March 2025	T	3:59:23	04:00:38	-0:01:15
10.	7 September 2025	T	15:29:38	15:30:52	-0:01:14

11.	3 March 2026	T	8:46:21	08:47:36	-0:01:15
12.	28 August 2026	P	1:25:08	01:26:24	-0:01:16
13.	20 February 2027*	N	21:15:01	21:13:45	-0:01:16
14.	17 August 2027	N	5:25:57	05:27:13	-0:01:16
15.	12 January 2028	P	2:08:56	02:10:12	-0:01:16
16.	6 July 2028	P	15:45:56	15:47:12	-0:01:16
17.	31 December 2028	T	14:04:56	14:06:13	-0:01:17
18.	26 June 2029	T	0:35:55	00:37:12	-0:01:17
19.	20 December 2029*	T	19:44:29	19:45:47	-0:01:18
20.	15 June 2030	P	16:14:45	16:16:03	-0:01:18
21.	9 December 2030*	N	20:10:06	20:11:25	-0:01:19
22.	7 May 2031	N	1:52:53	01:54:11	-0:01:18
23.	5 June 2031	N	10:58:13	10:59:32	-0:01:19

24.	30 October 2031	N	5:51:25	05:52:44	-0:01:19
25.	25 April 2032	T	12:22:58	12:24:17	-0:01:19
26.	18 October 2032	T	16:26:17	16:27:36	-0:01:19
27.	14 April 2033	T	16:12:52	16:14:12	-0:01:20
28.	8 October 2033	T	8:19:41	08:21:01	-0:01:20
29.	3 April 2034	N	16:54:31	16:55:51	-0:01:20
30.	28 September 2034	P	0:43:26	00:44:46	-0:01:20
Average of Difference in Value					-00:01:16
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.2 Time of First Contact with the Penumbra: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.2 it can be concluded that for the calculation of First Contact with the Penumbra, the results of Jean Meeus's calculations are faster than Ibn Ya'qūb al-Batāwy. Minimum difference of First Contact with the Penumbra is -0:01:12, a maximum difference is -0:01:20, and an average of difference in value is -00:01:16.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb	Difference in Value

				al-Batāwy	(Jean Meeus - Ibn Ya’qūb al-Batāwy)
			First Contact with the Umbra (UT)		
1.	26 May 2021	T	9:45:20	09:46:32	-0:01:12
2.	19 November 2021	P	7:20:14	07:21:26	-0:01:12
3.	16 May 2022	T	2:27:53	02:29:06	-0:01:13
4.	8 November 2022	T	9:09:57	09:11:10	-0:01:13
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	19:36:01	19:37:15	-0:01:14
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	2:14:41	02:15:55	-0:01:14
9.	14 March 2025	T	5:11:11	05:12:26	-0:01:15
10.	7 September 2025	T	16:27:55	16:29:10	-0:01:15
11.	3 March	T	9:51:35	09:52:50	-0:01:15

	2026				
12.	28 August 2026	P	2:34:42	02:35:57	-0:01:15
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	3:46:35	03:47:51	-0:01:16
16.	6 July 2028	P	17:10:33	17:11:50	-0:01:17
17.	31 December 2028	T	15:08:10	15:09:27	-0:01:17
18.	26 June 2029	T	1:33:29	01:34:46	-0:01:17
19.	20 December 2029*	T	20:56:21	20:57:39	-0:01:18
20.	15 June 2030	P	17:21:33	17:22:51	-0:01:18
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April	T	13:28:25	13:29:44	-0:01:19

	2032				
26.	18 October 2032	T	17:25:49	17:27:08	-0:01:19
27.	14 April 2033	T	17:25:51	17:27:11	-0:01:20
28.	8 October 2033	T	9:14:33	09:15:54	-0:01:21
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	2:37:27	02:38:48	-0:01:21
Average of Difference in Value					-00:01:16
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.3 Time of First Contact with the Umbra: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.3 it can be concluded that for the calculation of First Contact with the Umbra, Jean Meeus' calculation results are faster than Ibn Ya'qūb al-Batāwy's calculation. A minimum difference is -0:01:12, maximum difference is -0:01:21, average of difference in value is -00:01:16.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb al-Batāwy	Difference in Value (Jean Meeus - Ibn Ya'qūb al-
			Beginning of Total Phase (UT)		

					Batāwy)
1.	26 May 2021	T	11:12:53	11:14:05	-0:01:12
2.	19 November 2021	P	-	-	-
3.	16 May 2022	T	3:28:53	03:30:06	-0:01:13
4.	8 November 2022	T	10:17:01	10:18:14	-0:01:13
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	-	-	-
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	-	-	-
9.	14 March 2025	T	6:27:14	06:28:29	-0:01:15
10.	7 September 2025	T	17:31:13	17:32:28	-0:01:15
11.	3 March 2026	T	11:05:30	11:06:45	-0:01:15
12.	28 August 2026	P	-	-	-
13.	20 February	N	-	-	-

	2027*				
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	-	-	-
16.	6 July 2028	P	-	-	-
17.	31 December 2028	T	16:16:24	16:17:41	-0:01:17
18.	26 June 2029	T	2:32:04	02:33:21	-0:01:17
19.	20 December 2029*	T	22:15:44	22:17:01	-0:01:17
20.	15 June 2030	P	-	-	-
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	14:40:52	14:42:11	-0:01:19
26.	18 October 2032	T	18:40:07	18:41:27	-0:01:20
27.	14 April 2033	T	18:48:49	18:50:09	-0:01:20

28.	8 October 2033	T	10:16:07	10:17:27	-0:01:20
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	-	-	-
Average of Difference in Value					-0:01:16
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.4 Time of Beginning of Total Phase: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.4 it can be concluded that for the calculation of the Beginning of Total Phase, the results of Jean Meeus's calculations are faster than Ibn Ya'qūb al-Batāwy. A minimum difference is -0:01:12, a maximum difference is -0:01:20, and an average of difference in value is -00:01:16.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb al-Batāwy	Difference in Value (Jean Meeus - Ibn Ya'qūb al-Batāwy)
			Maximum of the Eclipse (UT)		
1.	26 May 2021	T	11:18:31	11:19:44	-0:01:13
2.	19 November	P	9:03:36	09:04:49	-0:01:13

	2021				
3.	16 May 2022	T	4:11:06	04:12:19	-0:01:13
4.	8 November 2022	T	10:59:15	11:00:28	-0:01:13
5.	5 May 2023	N	17:22:56	17:24:10	-0:01:14
6.	28 October 2023	P	20:14:09	20:15:23	-0:01:14
7.	25 March 2024	N	7:13:12	07:14:26	-0:01:14
8.	18 September 2024	P	2:44:40	02:45:55	-0:01:15
9.	14 March 2025	T	6:59:23	07:00:37	-0:01:14
10.	7 September 2025	T	18:11:56	18:13:11	-0:01:15
11.	3 March 2026	T	11:34:14	11:35:29	-0:01:15
12.	28 August 2026	P	4:13:01	04:14:16	-0:01:15
13.	20 February 2027*	N	23:13:00	23:14:15	-0:01:15
14.	17 August 2027	N	7:14:12	07:15:28	-0:01:16
15.	12 January	P	4:13:09	04:14:25	-0:01:16

	2028				
16.	6 July 2028	P	18:20:35	18:21:51	-0:01:16
17.	31 December 2028	T	16:51:44	16:53:01	-0:01:17
18.	26 June 2029	T	3:22:48	03:24:05	-0:01:17
19.	20 December 2029*	T	22:42:00	22:43:17	-0:01:17
20.	15 June 2030	P	18:33:09	18:34:27	-0:01:18
21.	9 December 2030*	N	22:28:16	22:29:34	-0:01:18
22.	7 May 2031	N	3:51:01	03:52:20	-0:01:19
23.	5 June 2031	N	11:44:17	11:45:36	-0:01:19
24.	30 October 2031	N	7:46:11	07:47:30	-0:01:19
25.	25 April 2032	T	15:13:44	15:15:04	-0:01:20
26.	18 October 2032	T	19:03:15	19:04:35	-0:01:20
27.	14 April 2033	T	19:12:47	19:14:07	-0:01:20
28.	8 October	T	10:55:10	10:56:31	-0:01:21

	2033				
29.	3 April 2034	N	19:06:06	19:07:26	-0:01:20
30.	28 September 2034	P	2:46:36	02:47:57	-0:01:21
Average of Difference in Value					-0:01:17
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.5 Time of Maximum of the Eclipse: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.5 it can be concluded that for the calculation of Maximum of the Eclipse, the results of Jean Meeus's calculations are faster than Ibn Ya'qūb al-Batāwy. A minimum difference is -0:01:13, a maximum difference is -0:01:21, and an average of difference in value is -00:01:17.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb al-Batāwy	Difference in Value (Jean Meeus - Ibn Ya'qūb al-Batāwy)
			End of Total Phase (UT)		
1.	26 May 2021	T	11:24:09	11:25:22	-0:01:13
2.	19 November 2021	P	-	-	-

3.	16 May 2022	T	4:53:20	04:54:33	-0:01:13
4.	8 November 2022	T	11:41:29	11:42:42	-0:01:13
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	-	-	-
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	-	-	-
9.	14 March 2025	T	7:31:31	07:32:46	-0:01:15
10.	7 September 2025	T	18:52:40	18:53:55	-0:01:15
11.	3 March 2026	T	12:02:58	12:04:13	-0:01:15
12.	28 August 2026	P	-	-	-
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	-	-	-
16.	6 July 2028	P	-	-	-

17.	31 December 2028	T	17:27:05	17:28:22	-0:01:17
18.	26 June 2029	T	4:13:32	04:14:50	-0:01:18
19.	20 December 2029*	T	23:08:16	23:09:33	-0:01:17
20.	15 June 2030	P	-	-	-
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	15:46:37	15:47:56	-0:01:19
26.	18 October 2032	T	19:26:24	19:27:43	-0:01:19
27.	14 April 2033	T	19:36:45	19:38:05	-0:01:20
28.	8 October 2033	T	11:34:14	11:35:34	-0:01:20
29.	3 April 2034	N	-	-	-
30.	28 September	P	-	-	-

	2034				
Average of Difference in Value					-0:01:16
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.6 Time of End of Total Phase: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.6 it can be concluded that for End of Total Phase calculations, the results of Jean Meeus' calculations are faster than Ibn Ya'qūb al-Batāwy. A minimum difference is -0:01:13, a maximum difference is -0:01:20, and an average of difference in value is -00:01:16.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb al-Batāwy	Difference in Value (Jean Meeus - Ibn Ya'qūb al-Batāwy)
			Last Contact with the Umbra (UT)		
1.	26 May 2021	T	12:51:43	12:52:55	-0:01:12
2.	19 November 2021	P	10:46:59	10:48:11	-0:01:12
3.	16 May 2022	T	5:54:20	05:55:33	-0:01:13
4.	8 November 2022	T	12:48:33	12:49:46	-0:01:13
5.	5 May 2023	N	-	-	-

6.	28 October 2023	P	20:52:17	20:53:31	-0:01:14
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	3:14:40	03:15:55	-0:01:15
9.	14 March 2025	T	8:47:34	08:48:49	-0:01:14
10.	7 September 2025	T	19:55:58	19:57:12	-0:01:14
11.	3 March 2026	T	13:16:52	13:18:08	-0:01:16
12.	28 August 2026	P	5:51:20	05:52:35	-0:01:15
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	4:39:44	04:41:00	-0:01:16
16.	6 July 2028	P	19:30:36	19:31:52	-0:01:16
17.	31 December 2028	T	18:35:19	18:36:36	-0:01:17
18.	26 June	T	5:12:07	05:13:25	-0:01:18

	2029				
19.	20 December 2029*	T	0:27:38	00:28:56	-0:01:18
20.	15 June 2030	P	19:44:46	19:46:04	-0:01:18
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	16:59:04	17:00:23	-0:01:19
26.	18 October 2032	T	20:40:42	20:42:02	-0:01:20
27.	14 April 2033	T	20:59:43	21:01:03	-0:01:20
28.	8 October 2033	T	12:35:48	12:37:08	-0:01:20
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	2:55:45	02:57:05	-0:01:20
Average of Difference in Value					-0:01:16
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.7 Time of Last Contact with the Umbra: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.7 it can be concluded that for the calculation of Last Contact with the Umbra, the results of Jean Meeus's calculations are faster than Ibn Ya'qūb al-Batāwy. A minimum difference is -0:01:12, a maximum difference is -0:01:20, and an average of difference in value is -00:01:16.

No.	Date	Eclipse Type	Jean Meeus	Ibn Ya'qūb al-Batāwy	Difference in Value (Jean Meeus - Ibn Ya'qūb al-Batāwy)
			Last Contact with the Penumbra (UT)		
1.	26 May 2021	T	13:48:51	13:50:03	-0:01:12
2.	19 November 2021	P	12:03:10	12:04:23	-0:01:13
3.	16 May 2022	T	6:49:53	06:51:06	-0:01:13
4.	8 November 2022	T	13:55:16	13:56:29	-0:01:13
5.	5 May 2023	N	19:30:43	19:31:57	-0:01:14
6.	28 October 2023	P	22:25:43	22:26:57	-0:01:14
7.	25 March	N	9:31:40	09:32:54	-0:01:14

	2024				
8.	18 September 2024	P	4:46:54	04:48:08	-0:01:14
9.	14 March 2025	T	9:59:22	10:00:37	-0:01:15
10.	7 September 2025	T	20:54:15	20:55:30	-0:01:15
11.	3 March 2026	T	14:22:07	14:23:22	-0:01:15
12.	28 August 2026	P	7:00:53	07:02:08	-0:01:15
13.	20 February 2027*	N	1:12:14	01:13:30	-0:01:16
14.	17 August 2027	N	9:02:27	09:03:43	-0:01:16
15.	12 January 2028	P	6:17:23	06:18:39	-0:01:16
16.	6 July 2028	P	20:55:13	20:56:30	-0:01:17
17.	31 December 2028	T	19:38:33	19:39:50	-0:01:17
18.	26 June 2029	T	6:09:42	06:10:59	-0:01:17
19.	20 December	T	1:39:30	01:40:47	-0:01:17

	2029*				
20.	15 June 2030	P	20:51:34	20:52:52	-0:01:18
21.	9 December 2030*	N	0:46:25	00:47:43	-0:01:18
22.	7 May 2031	N	5:49:10	05:50:29	-0:01:19
23.	5 June 2031	N	12:30:21	12:31:40	-0:01:19
24.	30 October 2031	N	9:40:56	09:42:15	-0:01:19
25.	25 April 2032	T	18:04:31	18:05:50	-0:01:19
26.	18 October 2032	T	21:40:14	21:41:34	-0:01:20
27.	14 April 2033	T	22:12:42	22:14:02	-0:01:20
28.	8 October 2033	T	13:30:40	13:32:00	-0:01:20
29.	3 April 2034	N	21:17:41	21:19:01	-0:01:20
30.	28 September 2034	P	4:49:46	04:51:07	-0:01:21
Average of Difference in Value					-00:01:17
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.8 Time of Last Contact with the Penumbra: Jean Meeus and Ibn Ya'qūb al-Batāwy

From Table 4.8 it can be concluded that for the calculation of Last Contact with the Penumbra, the calculation results of Jean Meeus are faster than Ibn Ya'qūb al-Batāwy. A minimum difference is -0:01:12, a maximum difference is -0:01:21, and an average of difference in value is -00:01:17.

Calculation's results of Jean Meeus and Ibn Ya'qūb al-Batāwy from tables 4.2 to 4.8 show that the algorithm data for calculating the lunar eclipse of Ibn Ya'qūb al-Batāwy is only slightly different from the minimum average of difference is -00:01:16 and maximum average of difference is -00:01:17. Thus, the effect of the simplification of the calculation steps and the difference in the use of delta T has no significant effect.

2. NASA dan Ibn Ya'qūb al-Batāwy

The author calculates the lunar eclipse reckoning algorithm of Ibn Ya'qūb al-Batāwy with an excel-based program as described earlier. Data from NASA the author took from the NASA website: http://www.eclipse.gsfc.nasa.gov/lunar.html. The author used data of 30 lunar eclipses from 2021-2034 (13 years), with details; 13 total lunar eclipses, 8 partial lunar eclipses, and 9 penumbral lunar eclipses, as follows:

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			First Contact with the Penumbra (UT)		
1.	26 May	T	08:47:39	08:49:24	-00:01:45

	2021				
2.	19 November 2021	P	06:02:09	06:05:15	-00:03:06
3.	16 May 2022	T	01:32:07	01:33:33	-00:01:26
4.	8 November 2022	T	08:02:17	08:04:27	-00:02:10
5.	5 May 2023	N	15:14:10	15:16:23	-00:02:13
6.	28 October 2023	P	18:01:47	18:03:50	-00:02:03
7.	25 March 2024	N	04:53:11	04:55:57	-00:02:46
8.	18 September 2024	P	00:41:02	00:43:41	-00:02:39
9.	14 March 2025	T	03:57:24	04:00:38	-00:03:14
10.	7 September 2025	T	15:28:21	15:30:52	-00:02:31
11.	3 March 2026	T	08:44:22	08:47:36	-00:03:14
12.	28 August 2026	P	01:23:55	01:26:24	-00:02:29
13.	20 February 2027*	N	21:12:20	21:13:45	-00:02:41

14.	17 August 2027	N	05:24:29	05:27:13	-00:02:44
15.	12 January 2028	P	02:07:37	02:10:12	-00:02:35
16.	6 July 2028	P	15:44:21	15:47:12	-00:02:51
17.	31 December 2028	T	14:03:49	14:06:13	-00:02:24
18.	26 June 2029	T	00:34:34	00:37:12	-00:02:38
19.	20 December 2029*	T	19:42:53	19:45:47	-00:02:54
20.	15 June 2030	P	16:14:09	16:16:03	-00:01:54
21.	9 December 2030*	N	20:07:56	20:11:25	-00:03:29
22.	7 May 2031	N	01:52:06	01:54:11	-00:02:05
23.	5 June 2031	N	10:56:16	10:59:32	-00:03:16
24.	30 October 2031	N	05:49:29	05:52:44	-00:03:15
25.	25 April 2032	T	12:22:16	12:24:17	-00:02:01
26.	18 October 2032	T	16:24:41	16:27:36	-00:02:55

27.	14 April 2033	T	16:11:54	16:14:12	-00:02:18
28.	8 October 2033	T	08:18:44	08:21:01	-00:02:17
29.	3 April 2034	N	16:52:54	16:55:51	-00:02:57
30.	28 September 2034	P	00:41:57	00:44:46	-00:02:49
Average of Difference in Value					-00:02:33
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.9 Time of First Contact with the Penumbra: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.9 it can be concluded that for the calculation of First Contact with the Penumbra, the results of NASA calculations are faster than Ibn Ya'qūb al-Batāwy. In this table, the largest difference occurred on 9 December 2030 is -00:03:29 and the smallest difference occurred on 20 February 2027 is -00:01:25. The average of difference in value for the calculation of First Contact with the Penumbra is -00:02:33.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			First Contact with the Umbra (UT)		

1.	26 May 2021	T	09:44:57	09:46:32	-00:01:35
2.	19 November 2021	P	07:18:41	07:21:26	-00:02:45
3.	16 May 2022	T	02:27:53	02:29:06	-00:01:13
4.	8 November 2022	T	09:09:12	09:11:10	-00:01:58
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	19:35:18	19:37:15	-00:01:57
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	02:12:48	02:15:55	-00:03:07
9.	14 March 2025	T	05:09:33	05:12:26	-00:02:53
10.	7 September 2025	T	16:27:02	16:29:10	-00:02:08
11.	3 March 2026	T	09:50:00	09:52:50	-00:02:50
12.	28 August 2026	P	02:33:48	02:35:57	-00:02:09
13.	20 February	N	-	-	-

	2027*				
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	03:45:00	03:47:51	-00:02:51
16.	6 July 2028	P	17:08:51	17:11:50	-00:02:59
17.	31 December 2028	T	15:07:35	15:09:27	-00:01:52
18.	26 June 2029	T	01:32:18	01:34:46	-00:02:28
19.	20 December 2029*	T	20:55:17	20:57:39	-00:02:22
20.	15 June 2030	P	17:21:03	17:22:51	-00:01:48
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	13:27:58	13:29:44	-00:01:46
26.	18 October 2032	T	17:24:22	17:27:08	-00:02:46
27.	14 April	T	17:25:03	17:27:11	-00:02:08

	2033				
28.	8 October 2033	T	09:13:50	09:15:54	-00:02:04
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	02:33:00	02:38:48	-00:05:48
Average of Difference in Value					-00:02:27
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.10 Time of First Contact with the Umbra: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.10 it can be concluded that for the calculation of First Contact with the Umbra, NASA's calculation results are faster than that of Ibn Ya'qūb al-Batāwy. In this table, the largest difference occurs on September 28, 2034 is -00:05:48 and the smallest difference occurs on May 16, 2022 is -00:01:13. Average of difference in value for First Contact with the Umbra calculation is -00:02:27.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			Beginning of Total Phase (UT)		
1.	26 May 2021	T	11:11:25	11:14:05	-00:02:40

2.	19 November 2021	P	-	-	-
3.	16 May 2022	T	03:29:03	03:30:06	-00:01:03
4.	8 November 2022	T	10:16:39	10:18:14	-00:01:35
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	-	-	-
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	-	-	-
9.	14 March 2025	T	06:25:59	06:28:29	-00:02:30
10.	7 September 2025	T	17:30:41	17:32:28	-00:01:47
11.	3 March 2026	T	11:04:26	11:06:45	-00:02:19
12.	28 August 2026	P	-	-	-
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-

15.	12 January 2028	P	-	-	-
16.	6 July 2028	P	-	-	-
17.	31 December 2028	T	16:16:19	16:17:41	-00:01:22
18.	26 June 2029	T	02:31:08	02:33:21	-00:02:13
19.	20 December 2029*	T	22:15:05	22:17:01	-00:01:56
20.	15 June 2030	P	-	-	-
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	14:40:47	14:42:11	-00:01:24
26.	18 October 2032	T	18:38:46	18:41:27	-00:02:41
27.	14 April 2033	T	18:47:56	18:50:09	-00:02:13
28.	8 October 2033	T	10:15:38	10:17:27	-00:01:49
29.	3 April	N	-	-	-

	2034				
30.	28 September 2034	P	-	-	-
Average of Difference in Value					-00:01:58
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.11 Time of Beginning of Total Phase: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.11 it can be concluded that for the calculation of the Beginning of Total Phase, the results of NASA calculations are faster than Ibn Ya'qūb al-Batāwy. In this table, the largest difference occurred on 18 October 2032 of -00:02:41 and the smallest difference occurred on 16 May 2022 of -00:01:03. Average of difference in value for Beginning of Total Phase calculation is -00:01:58.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			Maximum of the Eclipse (UT)		
1.	26 May 2021	T	11:18:40	11:19:44	-00:01:04
2.	19 November 2021	P	09:02:53	09:04:49	-00:01:56
3.	16 May 2022	T	04:11:28	04:12:19	-00:00:51

4.	8 November 2022	T	10:59:08	11:00:28	-00:01:20
5.	5 May 2023	N	17:22:51	17:24:10	-00:01:19
6.	28 October 2023	P	20:14:03	20:15:23	-00:01:20
7.	25 March 2024	N	07:12:45	07:14:26	-00:01:41
8.	18 September 2024	P	02:44:10	02:45:55	-00:01:45
9.	14 March 2025	T	06:58:41	07:00:37	-00:01:56
10.	7 September 2025	T	18:11:43	18:13:11	-00:01:28
11.	3 March 2026	T	11:33:37	11:35:29	-00:01:52
12.	28 August 2026	P	04:12:49	04:14:16	-00:01:27
13.	20 February 2027*	N	23:12:50	23:14:15	-00:01:25
14.	17 August 2027	N	07:13:43	07:15:28	-00:01:45
15.	12 January 2028	P	04:12:56	04:14:25	-00:01:29
16.	6 July 2028	P	18:19:40	18:21:51	-00:02:11

17.	31 December 2028	T	16:51:58	16:53:01	-00:01:03
18.	26 June 2029	T	03:22:05	03:24:05	-00:02:00
19.	20 December 2029*	T	22:41:54	22:43:17	-00:01:23
20.	15 June 2030	P	18:33:15	18:34:27	-00:01:12
21.	9 December 2030*	N	22:27:32	22:29:34	-00:02:02
22.	7 May 2031	N	03:50:43	03:52:20	-00:01:37
23.	5 June 2031	N	11:43:58	11:45:36	-00:01:38
24.	30 October 2031	N	07:45:26	07:47:30	-00:02:04
25.	25 April 2032	T	15:13:31	15:15:04	-00:01:33
26.	18 October 2032	T	19:02:20	19:04:35	-00:02:15
27.	14 April 2033	T	19:12:31	19:14:07	-00:01:36
28.	8 October 2033	T	10:55:02	10:56:31	-00:01:29
29.	3 April 2034	N	19:05:38	19:07:26	-00:01:48

30.	28 September 2034	P	02:46:16	02:47:57	-00:01:41
Average of Difference in Value					-00:01:36
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.12 Time of Maximum of the Eclipse: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.12 it can be concluded that for the calculation of Maximum of the Eclipse, NASA's calculation results are faster than Ibn Ya'qūb al-Batāwy. In this table the largest difference occurs on 18 October 2032 of -00:02:15 and the smallest difference occurs on 16 May 2022 of -00:00:51. Average of difference in value for Maximum of the Eclipse calculation is -00:01:36.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			End of Total Phase (UT)		
1.	26 May 2021	T	11:25:55	11:25:22	+00:00:33
2.	19 November 2021	P	-	-	-
3.	16 May 2022	T	04:53:56	04:54:33	-00:00:37
4.	8 November	T	11:41:37	11:42:42	-00:01:05

	2022				
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	-	-	-
7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	-	-	-
9.	14 March 2025	T	07:31:23	07:32:46	-00:01:23
10.	7 September 2025	T	18:52:47	18:53:55	-00:01:08
11.	3 March 2026	T	12:02:45	12:04:13	-00:01:28
12.	28 August 2026	P	-	-	-
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	-	-	-
16.	6 July 2028	P	-	-	-
17.	31 December 2028	T	17:27:40	17:28:22	-00:00:42

18.	26 June 2029	T	04:13:01	04:14:50	-00:01:49
19.	20 December 2029*	T	23:08:45	23:09:33	-00:00:48
20.	15 June 2030	P	-	-	-
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	15:46:19	15:47:56	-00:01:37
26.	18 October 2032	T	19:25:53	19:27:43	-00:01:50
27.	14 April 2033	T	19:37:09	19:38:05	-00:00:56
28.	8 October 2033	T	11:34:27	11:35:34	-00:01:07
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	-	-	-
Average of Difference in Value					-00:01:04
Note: the sign (*) explains the eclipse will occur until the next					

date

Table 4.13 Time of End of Total Phase: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.13 it can be concluded that for End of Total Phase calculations, most of NASA's calculations are faster than Ibn Ya'qūb al-Batāwy except on 26 May 2021, Ibn Ya'qūb al-Batāwy's calculations are faster by +00:00:33. In this table, the biggest difference occurs on 18 October 2032 of -00:01:50 and the smallest difference occurs on 26 May 2021 of +00:00:33. Average of difference in value for End of Total Phase calculation is -00:01:04.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			Last Contact with the Umbra (UT)		
1.	26 May 2021	T	12:52:22	12:52:55	-00:00:33
2.	19 November 2021	P	10:47:04	10:48:11	-00:01:07
3.	16 May 2022	T	05:55:07	05:55:33	-00:00:26
4.	8 November 2022	T	12:49:03	12:49:46	-00:00:43
5.	5 May 2023	N	-	-	-
6.	28 October 2023	P	20:52:39	20:53:31	-00:00:52

7.	25 March 2024	N	-	-	-
8.	18 September 2024	P	03:15:35	03:15:55	-00:00:20
9.	14 March 2025	T	08:47:48	08:48:49	-00:01:01
10.	7 September 2025	T	19:56:26	19:57:12	-00:00:46
11.	3 March 2026	T	13:17:10	13:18:08	-00:00:58
12.	28 August 2026	P	05:51:55	05:52:35	-00:00:40
13.	20 February 2027*	N	-	-	-
14.	17 August 2027	N	-	-	-
15.	12 January 2028	P	04:41:00	04:41:00	Sama
16.	6 July 2028	P	19:30:21	19:31:52	-00:01:31
17.	31 December 2028	T	18:36:24	18:36:36	-00:00:12
18.	26 June 2029	T	05:11:50	05:13:25	-00:01:35
19.	20	T	00:28:34	00:28:56	-00:00:22

	December 2029*				
20.	15 June 2030	P	19:45:25	19:46:04	-00:00:39
21.	9 December 2030*	N	-	-	-
22.	7 May 2031	N	-	-	-
23.	5 June 2031	N	-	-	-
24.	30 October 2031	N	-	-	-
25.	25 April 2032	T	16:59:09	17:00:23	-00:01:14
26.	18 October 2032	T	20:40:17	20:42:02	-00:01:45
27.	14 April 2033	T	21:00:02	21:01:03	-00:01:01
28.	8 October 2033	T	12:36:15	12:37:08	-00:00:53
29.	3 April 2034	N	-	-	-
30.	28 September 2034	P	02:59:42	02:57:05	+00:02:37
Average of Difference in Value					-00:00:40
Note: the sign (*) explains the eclipse will occur until the next date					

Table 4.14 Time of Last Contact with the Umbra: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.14 it can be concluded that for the calculation of Last Contact with the Umbra, most of the results of NASA calculations were faster than Ibn Ya'qūb al-Batāwy except on September 28, 2034, Ibn Ya'qūb al-Batāwy's calculations were faster by +00: 02:37. In this table, the biggest difference occurs on September 28, 2034, +00:02:37 and on January 12, 2028, the value of the two calculations is the same and has no difference. The average of difference in value for the calculation of Last Contact with the Umbra is -00: 00: 40.

No.	Date	Eclipse Type	NASA	Ibn Ya'qūb al-Batāwy	Difference in Value (NASA - Ibn Ya'qūb al-Batāwy)
			Last Contact with the Penumbra (UT)		
1.	26 May 2021	T	13:49:41	13:50:03	-00:00:22
2.	19 November 2021	P	12:03:08	12:04:23	-00:01:15
3.	16 May 2022	T	06:50:48	06:51:06	-00:00:18
4.	8 November 2022	T	13:56:08	13:56:29	-00:00:21
5.	5 May 2023	N	19:31:41	19:31:57	-00:00:16
6.	28 October	P	22:26:20	22:26:57	-00:00:37

	2023				
7.	25 March 2024	N	09:32:18	09:32:54	-00:00:36
8.	18 September 2024	P	04:47:18	04:48:08	-00:00:50
9.	14 March 2025	T	10:00:01	10:00:37	-00:00:36
10.	7 September 2025	T	20:55:00	20:55:30	-00:00:30
11.	3 March 2026	T	14:22:59	14:23:22	-00:00:23
12.	28 August 2026	P	07:01:41	07:02:08	-00:00:27
13.	20 February 2027*	N	01:13:19	01:13:30	-00:00:11
14.	17 August 2027	N	09:03:03	09:03:43	-00:00:40
15.	12 January 2028	P	06:18:18	06:18:39	-00:00:21
16.	6 July 2028	P	20:54:59	20:56:30	-00:01:31
17.	31 December 2028	T	19:40:02	19:39:50	+00:00:12
18.	26 June 2029	T	06:09:42	06:10:59	-00:01:17

19.	20 December 2029*	T	01:40:51	01:40:47	+00:00:04
20.	15 June 2030	P	20:52:23	20:52:52	-00:00:29
21.	9 December 2030*	N	00:47:09	00:47:43	-00:00:34
22.	7 May 2031	N	05:49:27	05:50:29	-00:01:02
23.	5 June 2031	N	12:31:49	12:31:40	+00:00:09
24.	30 October 2031	N	09:41:15	09:42:15	-00:01:00
25.	25 April 2032	T	18:04:42	18:05:50	-00:01:08
26.	18 October 2032	T	21:40:05	21:41:34	-00:01:29
27.	14 April 2033	T	22:13:05	22:14:02	-00:00:57
28.	8 October 2033	T	13:31:21	13:32:00	-00:00:39
29.	3 April 2034	N	21:18:19	21:19:01	-00:00:42
30.	28 September 2034	P	04:50:38	04:51:07	-00:00:29
Average of Difference in Value					-00:00:37
Note: the sign (*) explains the eclipse will occur until the next					

date

Table 4.15 Time of Last Contact with the Penumbra: NASA and Ibn Ya'qūb al-Batāwy

From Table 4.15 it can be concluded that for the calculation of Last Contact with the Penumbra, most of NASA's calculation results are faster than Ibn Ya'qūb al-Batāwy except on December 31, 2028, December 20, 2029, and June 5, 2031. In this table, the largest difference occurred on 6 July 2028 of -00:01:31 and the smallest difference occurred on 20 December 2029 of +00: 00: 04. The average of difference in value for the calculation of Last Contact with the Penumbra is -00: 00: 37.

The following table is a calculation results of the **minimum difference values** for each eclipse phase using the lunar eclipse calculation algorithm of Ibn Ya'qūb al-Batāwy with Jean Meeus and NASA:

Phases	Jean Meeus - Ibn Ya'qūb al-Batāwy	NASA - Ibn Ya'qūb al-Batāwy
P1	-0:01:12	-00:01:25
U1	-0:01:12	-00:01:13
U2	-0:01:12	-00:01:03
Maximum of the Eclipse	-0:01:13	-00:00:51
U3	-0:01:13	+00:00:33
U4	-0:01:12	00:00:00
P4	-0:01:12	+00: 00: 04

Table 4.16 Calculation results of the minimum difference values of Ibn Ya'qūb al-Batāwy, Jean Meeus, and NASA's lunar eclipse algorithm.

The following table is a calculation results of the **maximum difference values** for each eclipse phase using the lunar eclipse calculation algorithm of Ibn Ya'qūb al-Batāwy with Jean Meeus and NASA:

Phases	Jean Meeus - Ibn Ya'qūb al-Batāwy	NASA - Ibn Ya'qūb al-Batāwy
P1	-0:01:20	-00:03:29
U1	-0:01:21	-00:05:48
U2	-0:01:20	-00:02:41
Maximum of the Eclipse	-0:01:21	-00:02:15
U3	-0:01:20	-00:01:50
U4	-0:01:20	+00:02:37
P4	-0:01:21	-00:01:31

Table 4.17 Calculation results of the maximum difference values of Ibn Ya'qūb al-Batāwy, Jean Meeus, and NASA's lunar eclipse algorithm.

The following is the average data for calculation results of 30 lunar eclipses from 2021-2034 (13 years), with details; 13 total lunar eclipses, 8 partial lunar eclipses, and 9 penumbral lunar eclipses using Ibn Ya'qūb al-Batāwy's lunar eclipse calculation algorithm with Jean Meeus, and NASA:

Phases	Jean Meeus - Ibn Ya'qūb al-Batāwy	NASA - Ibn Ya'qūb al-Batāwy
P1	-00:01:16	-00:02:33

U1	-00:01:16	-00:02:27
U2	-0:01:16	-00:01:58
Maximum of the Eclipse	-0:01:17	-00:01:36
U3	-0:01:16	-00:01:04
U4	-0:01:16	-00:00:40
P4	-00:01:17	-00:00:37

Table 4.18 Calculation results of the average values of Ibn Ya'qūb al-Batāwy, Jean Meeus, and NASA's lunar eclipse algorithm.

From the calculation results of 2 reckoning lunar eclipses; Jean Meeus, and NASA. The author concludes that Ibn Ya'qūb al-Batāwy's lunar eclipse calculation algorithm in the *Risālah az-Zain* book has good accuracy. We can see this from the calculation results above. However, Ibn Ya'qūb al-Batāwy's lunar eclipse calculation algorithm in Risālah az-Zain's book can only determine the time of first contact with the penumbra, first contact with the umbra, beginning of total phase, maximum of the eclipse, end of total phase, last contact with the umbra, and last contact with the penumbra. It has not yet been determined which areas will experience a lunar eclipse and it is not possible to determine the phase of a lunar eclipse that occurs in a particular place, whether that place experiences the entire eclipse process or only a few phases or not at all.

CHAPTER V

CONCLUSION AND RECOMMENDATION

A. Conclusion

1. The lunar eclipse reckoning algorithm in the Book *Risālah az-Zain* is included in the category of *hisāb haqiqi contemporary* and the lunar eclipse reckoning algorithm in the Book Risālah az-Zain uses the Jean Meeus Algorithm but there are some formulas that are different such as calculating the value of K (estimated year of the eclipse), simplification of the formula F (argument for the latitude of the Moon), formula for calculating the value of A (additional correction to get the value of C), correction formula to determine the value of C (time of maximum eclipse), determination of Pasaran when the eclipse occurs, and deletion of the Delta T formula. The abolition of the Delta T formula aims to make it easier for beginners to understand the calculations, but this deletion does not have a significant effect on the results of the calculation.
2. The lunar eclipse reckoning algorithm in the Book *Risālah az-Zain* has good accuracy with the following consideration:
   a. The result from the calculation of the lunar eclipse of *Risālah az-Zain* and Jean Meeus differs slightly with the largest average difference of -0:01:21 in the phase of first contact with the umbra, maximum of the eclipse, and last contact

with the penumbra. The smallest difference is -0:01:12 in the first contact with the penumbra phase, first contact with the umbra, beginning of total phase, last contact with the umbra, and last contact with the penumbra.

b. The result of data from the calculation of *Risālah az-Zain's* lunar eclipse with NASA is slightly different, with the largest average difference of -00:05:48 in the first contact with the umbra phase. The smallest difference is 00:00:00 / has no difference in the last contact phase with the umbra.

B. Recommendation

1. The reckoning of the lunar eclipse of Ibn Ya'qūb al-Batāwy in the *Risālah az-Zain* book has good accuracy with systematic calculation steps and is easy to understand for beginners because the book describes steps and examples simultaneously. But there is still a need for refinement, it is necessary to add calculations to determine the coverage area that will be passed by the lunar eclipse and moonrise and moonset calculations to determine the state of the eclipse in a certain place.
2. In the chapter *al-Kusūfaini* (Two Eclipses), Ibn Ya'qūb al-Batāwy does not include a formula for calculating the value of E (eccentricity value of the Earth's orbit around the Sun), JDE WD (Julian date adjusted to the time of

the area), and Z (value to determine the days and markets when the eclipse occurs), but listed them in the previous chapter; *Awjah al-Qamar* (Phases of the Moon). Therefore, it is necessary to rewrite the formula in chapter *al-Kusūfaini* (Two Eclipses) so that the readers are not confused by the ambiguous formula and can calculate in more systematic and coherent ways.

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ATTACHMENT

Attachment 1

Calculation of the Total Lunar Eclipse May 26, 2021
Book of *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

GERHANA BULAN		
Y	1442	
M	10	
TZ	0	
Y	1442,83	
k	264,50	
T	0,213850	
JDE	2459360,938421	
M	140,920247	140°55'13''
M'	10,144174	10°08'39''
Ω	71,161264	71°09'41''
F	173,033505	173°02'01''
Imkan	0,1213	Mungkin
E	0,999462	00°59'58''
A	-0,000158	-00°00'01''
C1	-0,071595	-00°04'18''
C2	0,108812	00°06'32''
C3	0,005583	00°00'20''
C4	0,002336	00°00'08''
C5	-0,005525	-00°00'20''
C6	-0,002418	-00°00'09''
C7	-0,000938	-00°00'03''
C8	-0,002054	-00°00'07''
C9	-0,000079	-00°00'00''
C10	0,000193	00°00'01''
C11	-0,000203	-00°00'01''
C12	-0,000240	-00°00'01''
C13	-0,000085	-00°00'00''
C14	0,000172	00°00'01''
C15	-0,000189	-00°00'01''
C	0,033769	00°02'02''
JDE TD	2459361,472032	
JDE WD	2459361,472032	
GMT	11,328758	11:19:44
WD	11,328758	11:19:44
Z	2459361	
α	16	
A	2459374	
B	2460898	
C	6737	
D	2460689	
E	6	
TGL	26	
BLN	5	
THN	2021	
HA	4	
Pa	2	
P1	0,130423	00°07'50''
P2	-0,002348	-00°00'08''
P3	-0,006904	-00°00'25''
P4	0,004022	00°00'14''
P5	-0,003530	-00°00'13''
P6	-0,005071	-00°00'18''
P7	-0,002841	-00°00'10''
P	0,113751	00°06'50''
Q1	0,003724	00°00'13''
Q2	0,000410	00°00'01''
Q3	-0,324743	-00°19'29''
Q4	0,005248	00°00'19''
Q5	-0,002676	-00°00'10''
Q	4,902663	04°54'10''
u1	-0,003569	-00°00'13''
u2	-0,017915	-00°01'04''
u3	0,000375	00°00'01''
u4	0,000438	00°00'02''
u	-0,014772	-00°00'53''
W	0,9926	00°59'33''
Y	0,4794	00°28'46''
h	1,542528	01°32'33''
p	1,027572	01°01'39''
t	0,482572	00°28'57''
n	0,585175	00°35'07''
MP	1,9506	
MU	1,0058	
TP	2,505458	02:30:20
TU	1,553163	01:33:11
TT	0,093914	00:05:38
TE	Total	
DP	5,010915	05:00:39
DU	3,106327	03:06:23

	GERHANA BULAN	
Y	1442	
M	10	
TZ	0	
	KESIMPULAN	
	Gerhana	Syawwāl 1442
	Pada	26 Mei 2021
	Hari	Rabu Pahing
	Awal Penumbra	08:49:24
	Awal Umbra	09:46:32
	Awal Total	11:14:05
	Puncak Gerhana	11:19:44
	Akhir Total	11:25:22
	Akhir Umbra	12:52:55
	Akhir Penumbra	13:50:03
	Gamma	0,4794
	Mag Penumbra	1,9506
	Mag Umbra	1,0058
	Tipe	Total
	Durasi Penumbra	05:00:39
	Durasi Umbra	03:06:23
	Durasi Total	00:11:16

Calculation of the Partial Lunar Eclipse November 19, 2021
Book of *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

GERHANA BULAN		
Y	1443	
M	4	
TZ	0	
Y	1443,33	
k	270,50	
T	0,218701	
JDE	2459538,121954	
M	315,552387	315°33'09''
M'	165,045808	165°02'45''
Ω	61,778733	61°46'43''
F	357,058259	357°03'30''
Imkan	0,0513	Mungkin
E	0,999449	00°59'58''
A	-0,000155	-00°00'01''
C1	-0,104896	-00°06'18''
C2	-0,120868	-00°07'15''
C3	-0,008028	-00°00'29''
C4	0,000994	00°00'04''
C5	-0,003592	-00°00'13''
C6	-0,004301	-00°00'15''
C7	-0,000363	-00°00'01''
C8	-0,002098	-00°00'08''
C9	0,000427	00°00'02''
C10	-0,000577	-00°00'02''
C11	-0,000282	-00°00'01''
C12	0,000231	00°00'01''
C13	0,000125	00°00'00''
C14	-0,000050	-00°00'00''
C15	-0,000176	-00°00'01''
C	-0,243455	-00°14'36''
JDE TD	2459538,378344	
JDE WD	2459538,378344	
GMT	9,080247	09:04:49
WD	9,080247	09:04:49
Z	2459538	
α	16	
A	2459551	
B	2461075	
C	6737	
D	2460689	
E	12	
TGL	19	
BLN	11	
THN	2021	
HA	6	
Pa	4	
P1	-0,144873	-00°08'42''
P2	-0,002398	-00°00'09''
P3	-0,010115	-00°00'36''
P4	-0,005784	-00°00'21''
P5	-0,006280	-00°00'23''
P6	-0,003297	-00°00'12''
P7	-0,001210	-00°00'04''
P	-0,173957	-00°10'26''
Q1	-0,003425	-00°00'12''
Q2	0,000039	00°00'00''
Q3	0,318727	00°19'07''
Q4	0,003052	00°00'11''
Q5	-0,003567	-00°00'13''
Q	5,535527	05°32'08''
u1	0,003282	00°00'12''
u2	0,017584	00°01'03''
u3	0,000347	00°00'01''
u4	0,000255	00°00'01''
u	0,027367	00°01'39''
W	0,9987	00°59'55''
Y	-0,4556	-00°27'20''
h	1,584667	01°35'05''
p	0,985433	00°59'08''
t	0,440433	00°26'26''
n	0,507155	00°30'26''
MP	2,0716	
MU	0,9721	
TP	2,992686	02:59:34
TU	1,722904	01:43:22
TT	#NUM!	#NUM!
TE	Sebagian	
DP	5,985373	05:59:07
DU	3,445807	03:26:45
DT	#NUM!	#NUM!

	GERHANA BULAN	
Y	1443	
M	4	
TZ	0	
	KESIMPULAN	
	Gerhana	Rabī'uṡṡānī 1443
	Pada	19 November 2021
	Hari	Jum'at Wage
	Awal Penumbra	06:05:15
	Awal Umbra	07:21:26
	Awal Total	
	Puncak Gerhana	09:04:49
	Akhir Total	
	Akhir Umbra	10:48:11
	Akhir Penumbra	12:04:23
	Gamma	-0,4556
	Mag Penumbra	2,0716
	Mag Umbra	0,9721
	Tipe	Sebagian
	Durasi Penumbra	05:59:07
	Durasi Umbra	03:26:45
	Durasi Total	

Calculation of the Partial Lunar Eclipse May 16, 2022

Book of *Risālah az-Zain* by Ibn Ya'qūb al-Batāwy

GERHANA BULAN		
Y	1443	
M	10	
TZ	0	
Y	1443,83	
k	276,50	
T	0,223552	
JDE	2459715,305488	
M	130,184527	130°11'04''
M'	319,947443	319°56'51''
Ω	52,396203	52°23'46''
F	181,083641	181°05'01''
Imkan	0,0189	Mungkin
E	0,999437	00°59'58''
A	-0,000152	-00°00'01''
C1	0,261579	00°15'42''
C2	0,131863	00°07'55''
C3	-0,015861	-00°00'57''
C4	-0,000367	-00°00'01''
C5	-0,001237	-00°00'04''
C6	-0,004997	-00°00'18''
C7	0,001546	00°00'06''
C8	-0,002069	-00°00'07''
C9	-0,000737	-00°00'03''
C10	0,000460	00°00'02''
C11	0,000346	00°00'01''
C12	-0,000222	-00°00'01''
C13	-0,000157	-00°00'01''
C14	-0,000101	-00°00'00''
C15	-0,000158	-00°00'01''
C	0,369887	00°22'12''
JDE TD	2459716,175223	
JDE WD	2459716,175223	
GMT	4,205344	04:12:19
WD	4,205344	04:12:19
Z	2459716	
α	16	
A	2459729	
B	2461253	
C	6738	
D	2461054	
E	6	
TGL	16	
BLN	5	
THN	2022	
HA	2	
Pa	2	
P1	0,158053	00°09'29''
P2	-0,002365	-00°00'09''
P3	0,025225	00°01'31''
P4	-0,011427	-00°00'41''
P5	-0,007296	-00°00'26''
P6	-0,001135	-00°00'04''
P7	0,000446	00°00'02''
P	0,161500	00°09'41''
Q1	0,003095	00°00'11''
Q2	-0,000334	-00°00'01''
Q3	-0,252523	-00°15'09''
Q4	0,000014	00°00'00''
Q5	-0,004038	-00°00'15''
Q	4,966913	04°58'01''
u1	-0,002966	-00°00'11''
u2	-0,013931	-00°00'50''
u3	0,000069	00°00'00''
u4	0,000001	00°00'00''
u	-0,010928	-00°00'39''
W	0,9998	00°59'59''
Y	-0,2542	-00°15'15''
h	1,546372	01°32'47''
p	1,023728	01°01'25''
t	0,478728	00°28'43''
n	0,576418	00°34'35''
MP	2,3710	
MU	1,4120	
TP	2,646237	02:38:46
TU	1,720402	01:43:13
TT	0,703788	00:42:14
TE	Total	
DP	5,292474	05:17:33
DU	3,440804	03:26:27
DT	1,407575	01:24:27

	GERHANA BULAN	
Y	1443	
M	10	
TZ	0	
	KESIMPULAN	
	Gerhana	Syawwāl 1443
	Pada	16 Mei 2022
	Hari	Senin Pahing
	Awal Penumbra	01:33:33
	Awal Umbra	02:29:06
	Awal Total	03:30:06
	Puncak Gerhana	04:12:19
	Akhir Total	04:54:33
	Akhir Umbra	05:55:33
	Akhir Penumbra	06:51:06
	Gamma	-0,2542
	Mag Penumbra	2,3710
	Mag Umbra	1,4120
	Tipe	Total
	Durasi Penumbra	05:17:33
	Durasi Umbra	03:26:27
	Durasi Total	01:24:27

Attachment 2

Calculation of the Total Lunar Eclipse May 26, 2021
Book *Astronomical Algorithm* by Jean Meeus

INPUT

Masukkan perkiraan tanggal, bulan dan tahun =	26	5	2021	
Perkiraan nilai k =	264,509			
Nilai k untuk mengecek gerhana matahari =	265			
Nilai k untuk mengecek gerhana bulan =	264,5			
Masukkan nilai k (bulat atau bulat + 0.5) =	264,5			
Cek jenis gerhana =	CEK GERHANA BULAN			

Gerhana Bulan

Tipe Gerhana Bulan =	**GERHANA BULAN TOTAL**			
Awal fase penumbra (P1) pada tanggal	**26 Mei 2021**	pukul	**8:48:12**	UT
Awal fase umbra (U1) pada tanggal	**26 Mei 2021**	pukul	**9:45:20**	UT
Awal fase total (U2) pada tanggal	**26 Mei 2021**	pukul	**11:12:53**	UT
Gerhana bulan maksimum pada tanggal	**26 Mei 2021**	pukul	**11:18:31**	UT
Akhir fase total (U3) pada tanggal	**26 Mei 2021**	pukul	**11:24:09**	UT
Akhir fase umbra (U4) pada tanggal	**26 Mei 2021**	pukul	**12:51:43**	UT
Akhir fase penumbra (P4) pada tanggal	**26 Mei 2021**	pukul	**13:48:51**	UT
Magnitude Gerhana Penumbra =	**1,9506**			
Magnitude Gerhana Umbra =	**1,0058**			

DETIL PERHITUNGAN

Delta_T = TD - UT =	72,4	detik		
T =	0,2138496988			
E =	0,999461616			
Argumen Lintang bulan (F) =	173,05873	derajat =	3,020445	radian
Anomali rata-rata matahari (M) =	140,92025	derajat =	2,459522	radian
Anomali rata-rata bulan (M') =	10,14417	derajat =	0,177049	radian
Bujur titik naik bulan (Omega) =	71,16129	derajat =	1,241999	radian
F1 =	173,03351	derajat =	3,020004	radian
A1 =	328,17900	derajat =	5,727804	radian
P =	0,11375	derajat =	0,001985	radian
Q =	4,90266	derajat =	0,085568	radian
W =	0,992617			
Gamma =	0,479432			
u =	-0,014772			

Detil perhitungan gerhana bulan

Cek Gerhana Bulan (Ya/Tidak) =	YA				
Radius penumbra =	1,2700				
Radius umbra =	0,7551				
Magnitude Gerhana Penumbra =	1,9506				
Magnitude Gerhana Umbra =	1,0058				
H_Penumbra =	1,5425				
P_Umbra =	1,0276				
T_Umbra =	0,4826				
n_Umbra =	0,5852				
Semi Durasi Fase Penumbra =	150,33	menit			
Semi durasi Fase Parsial =	93,19	menit			
Semi durasi Fase Total =	5,64	menit			
Tipe Gerhana Bulan =	GERHANA BULAN TOTAL				
JDE belum terkoreksi =	2459360,938421				
Koreksi JDE =	0,033611				
JDE terkoreksi =	2459360,972032				
JD terkoreksi =	2459360,971194		Tanggal	Waktu	
JD awal fase penumbra (P1) =	2459360,866800	=	26 Mei 2021	8:48:12	UT
JD awal fase umbra (U1) =	2459360,906479	=	26 Mei 2021	9:45:20	UT
JD awal fase total (U2) =	2459360,967281	=	26 Mei 2021	11:12:53	UT
JD gerhana maksimum =	2459360,971194	=	26 Mei 2021	11:18:31	UT
JD akhir fase total (U3) =	2459360,975107	=	26 Mei 2021	11:24:09	UT
JD akhir fase umbra (U4) =	2459361,035909	=	26 Mei 2021	12:51:43	UT
JD akhir fase penumbra (P4) =	2459361,075588	=	26 Mei 2021	13:48:51	UT

Menghitung Delta T

Tahun =	2021,4	
1900 sd 1920	0,0	
1920 sd 1941	0,0	
1941 sd 1961	0,0	
1961 sd 1986	0,0	
1986 sd 2005	0,0	
2005 sd 2050	72,4	
2050 sd 2150	0,0	
2150 sd 2200	0,0	
Delta T =	72,4	detik

Calculation of the Partial Lunar Eclipse November 19, 2021
Book *Astronomical Algorithm* by Jean Meeus

INPUT

Masukkan perkiraan tanggal, bulan dan tahun =	19	11	2021
Perkiraan nilai k =	270,456		
Nilai k untuk mengecek gerhana matahari =	270		
Nilai k untuk mengecek gerhana bulan =	270,5		
Masukkan nilai k (bulat atau bulat + 0.5) =	270,5		
Cek jenis gerhana =	CEK GERHANA BULAN		

Gerhana Bulan

Tipe Gerhana Bulan =	**GERHANA BULAN PARSIAL**			
Awal fase penumbra (P1) pada tanggal	**19 November 2021**	pukul	**6:04:03**	UT
Awal fase umbra (U1) pada tanggal	**19 November 2021**	pukul	**7:20:14**	UT
Awal fase total (U2) pada tanggal	**TIDAK ADA**	pukul	**TIDAK ADA**	UT
Gerhana bulan maksimum pada tanggal	**19 November 2021**	pukul	**9:03:36**	UT
Akhir fase total (U3) pada tanggal	**TIDAK ADA**	pukul	**TIDAK ADA**	UT
Akhir fase umbra (U4) pada tanggal	**19 November 2021**	pukul	**10:46:59**	UT
Akhir fase penumbra (P4) pada tanggal	**19 November 2021**	pukul	**12:03:10**	UT
Magnitude Gerhana Penumbra =	**2,0716**			
Magnitude Gerhana Umbra =	**0,9721**			

DETIL PERHITUNGAN

Delta_T = TD - UT =	72,6	detik		
T =	0,2187007317			
E =	0,999449395			
Argumen Lintang bulan (F) =	357,08174	derajat =	6,232252	radian
Anomali rata-rata matahari (M) =	315,55239	derajat =	5,507428	radian
Anomali rata-rata bulan (M') =	165,04581	derajat =	2,880593	radian
Bujur titik naik bulan (Omega) =	61,77875	derajat =	1,078243	radian
F1 =	357,05826	derajat =	6,231842	radian
A1 =	328,82343	derajat =	5,739051	radian
P =	-0,17396	derajat =	-0,003036	radian
Q =	5,53553	derajat =	0,096613	radian
W =	0,998682			
Gamma =	-0,455620			
u =	0,027367			

Detil perhitungan gerhana bulan

Cek Gerhana Bulan (Ya/Tidak) =	YA				
Radius penumbra =	1,3122				
Radius umbra =	0,7129				
Magnitude Gerhana Penumbra =	2,0716				
Magnitude Gerhana Umbra =	0,9721				
H_Penumbra =	1,5847				
P_Umbra =	0,9854				
T_Umbra =	0,4404				
n_Umbra =	0,5072				
Semi Durasi Fase Penumbra =	179,56	menit			
Semi durasi Fase Parsial =	103,37	menit			
Semi durasi Fase Total =	TIDAK ADA	menit			
Tipe Gerhana Bulan =	GERHANA BULAN PARSIAL				
JDE belum terkoreksi =	2459538,121954				
Koreksi JDE =	-0,243611				
JDE terkoreksi =	2459537,878344				
JD terkoreksi =	2459537,877503		Tanggal	Waktu	
JD awal fase penumbra (P1) =	2459537,752808	=	19 November 2021	6:04:03	UT
JD awal fase umbra (U1) =	2459537,805715	=	19 November 2021	7:20:14	UT
JD awal fase total (U2) =	TIDAK ADA	=	TIDAK ADA	TIDAK ADA	UT
JD gerhana maksimum =	2459537,877503	=	19 November 2021	9:03:36	UT
JD akhir fase total (U3) =	TIDAK ADA	=	TIDAK ADA	TIDAK ADA	UT
JD akhir fase umbra (U4) =	2459537,949291	=	19 November 2021	10:46:59	UT
JD akhir fase penumbra (P4) =	2459538,002198	=	19 November 2021	12:03:10	UT

Menghitung Delta T

Tahun =	2021,9	
1900 sd 1920	0,0	
1920 sd 1941	0,0	
1941 sd 1961	0,0	
1961 sd 1986	0,0	
1986 sd 2005	0,0	
2005 sd 2050	72,6	
2050 sd 2150	0,0	
2150 sd 2200	0,0	
Delta T =	72,6	detik

Calculation of the Total Lunar Eclipse May 16, 2022
Book *Astronomical Algorithm* by Jean Meeus

INPUT				
Masukkan perkiraan tanggal, bulan dan tahun =	16	5	2022	
Perkiraan nilai k =	276,539			
Nilai k untuk mengecek gerhana matahari =	277			
Nilai k untuk mengecek gerhana bulan =	276,5			
Masukkan nilai k (bulat atau bulat + 0.5) =	276,5			
Cek jenis gerhana =	CEK GERHANA BULAN			

Gerhana Bulan				
Tipe Gerhana Bulan =	**GERHANA BULAN TOTAL**			
Awal fase penumbra (P1) pada tanggal	**16 Mei 2022**	pukul	**1:32:20**	UT
Awal fase umbra (U1) pada tanggal	**16 Mei 2022**	pukul	**2:27:53**	UT
Awal fase total (U2) pada tanggal	**16 Mei 2022**	pukul	**3:28:53**	UT
Gerhana bulan maksimum pada tanggal	**16 Mei 2022**	pukul	**4:11:06**	UT
Akhir fase total (U3) pada tanggal	**16 Mei 2022**	pukul	**4:53:20**	UT
Akhir fase umbra (U4) pada tanggal	**16 Mei 2022**	pukul	**5:54:20**	UT
Akhir fase penumbra (P4) pada tanggal	**16 Mei 2022**	pukul	**6:49:53**	UT
Magnitude Gerhana Penumbra =	**2,3710**			
Magnitude Gerhana Umbra =	**1,4120**			

DETIL PERHITUNGAN

Delta_T = TD - UT =	72,9	detik		
T =	0,2235517646			
E =	0,999437174			
Argumen Lintang bulan (F) =	181,10475	derajat =	3,160874	radian
Anomali rata-rata matahari (M) =	130,18453	derajat =	2,272149	radian
Anomali rata-rata bulan (M') =	319,94744	derajat =	5,584136	radian
Bujur titik naik bulan (Omega) =	52,39622	derajat =	0,914487	radian
F1 =	181,08364	derajat =	3,160506	radian
A1 =	329,46785	derajat =	5,750299	radian
P =	0,16150	derajat =	0,002819	radian
Q =	4,96691	derajat =	0,086689	radian
W =	0,999821			
Gamma =	-0,254180			
u =	-0,010928			

Detil perhitungan gerhana bulan

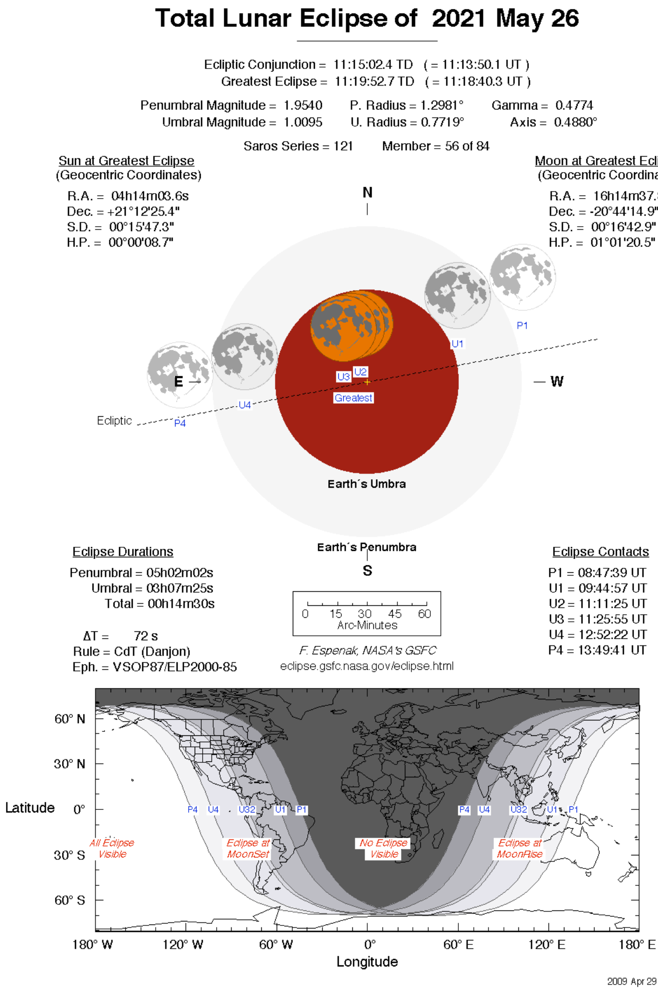
Cek Gerhana Bulan (Ya/Tidak) =	YA				
Radius penumbra =	1,2739				
Radius umbra =	0,7512				
Magnitude Gerhana Penumbra =	2,3710				
Magnitude Gerhana Umbra =	1,4120				
H_Penumbra =	1,5464				
P_Umbra =	1,0237				
T_Umbra =	0,4787				
n_Umbra =	0,5764				
Semi Durasi Fase Penumbra =	158,77	menit			
Semi durasi Fase Parsial =	103,22	menit			
Semi durasi Fase Total =	42,23	menit			
Tipe Gerhana Bulan =	GERHANA BULAN TOTAL				
JDE belum terkoreksi =	2459715,305488				
Koreksi JDE =	0,369735				
JDE terkoreksi =	2459715,675223				
JD terkoreksi =	2459715,674379		Tanggal	Waktu	
JD awal fase penumbra (P1) =	2459715,564119	=	16 Mei 2022	1:32:20	UT
JD awal fase umbra (U1) =	2459715,602695	=	16 Mei 2022	2:27:53	UT
JD awal fase total (U2) =	2459715,645054	=	16 Mei 2022	3:28:53	UT
JD gerhana maksimum =	2459715,674379	=	16 Mei 2022	4:11:06	UT
JD akhir fase total (U3) =	2459715,703703	=	16 Mei 2022	4:53:20	UT
JD akhir fase umbra (U4) =	2459715,746062	=	16 Mei 2022	5:54:20	UT
JD akhir fase penumbra (P4) =	2459715,784639	=	16 Mei 2022	6:49:53	UT

Menghitung Delta T

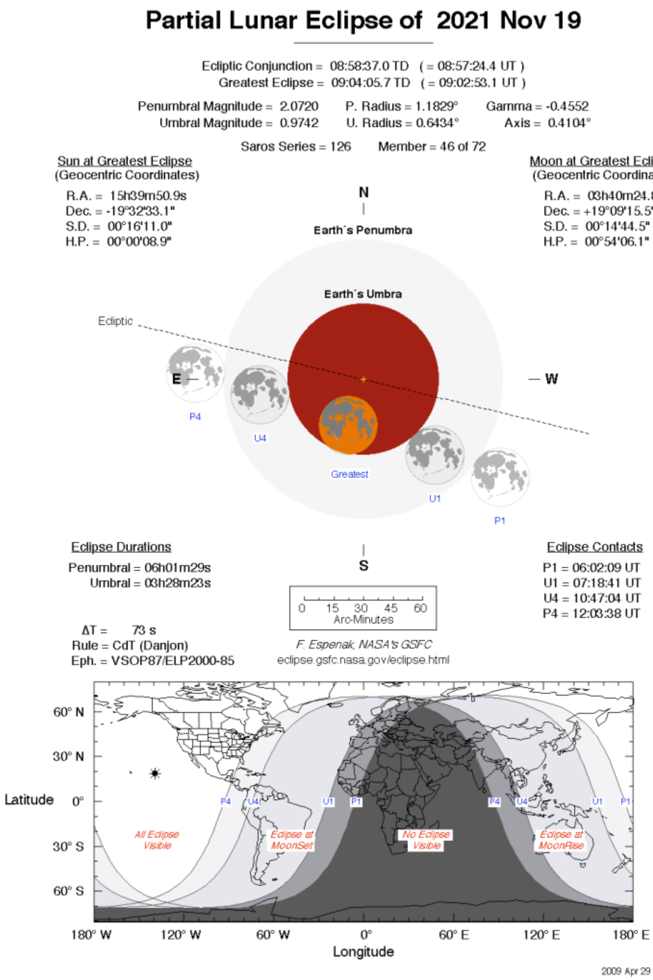
Tahun =	2022,4	
1900 sd 1920	0,0	
1920 sd 1941	0,0	
1941 sd 1961	0,0	
1961 sd 1986	0,0	
1986 sd 2005	0,0	
2005 sd 2050	72,9	
2050 sd 2150	0,0	
2150 sd 2200	0,0	
Delta T =	72,9	detik

Attachment 3

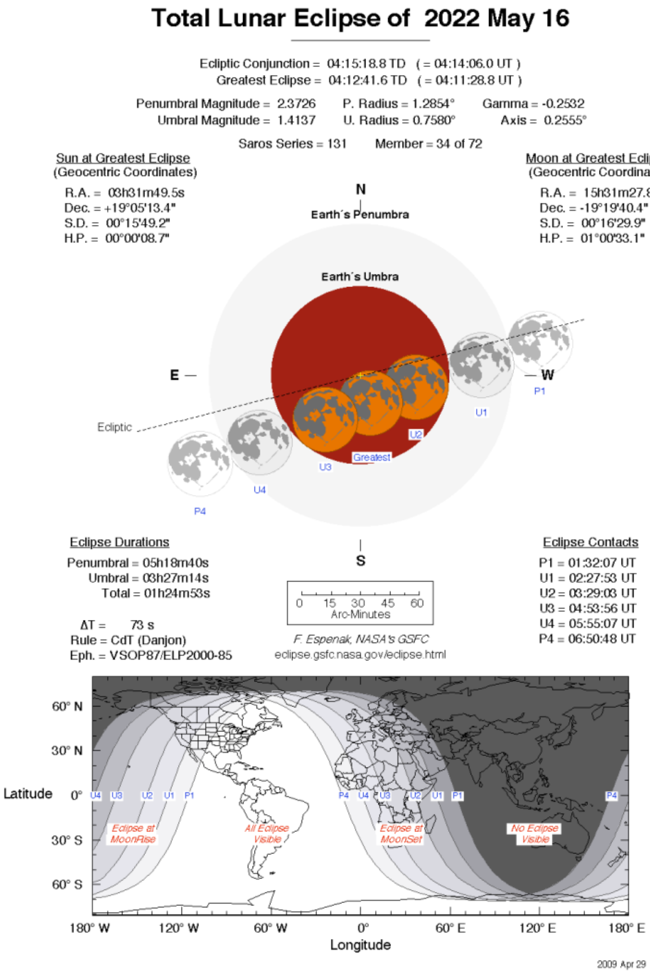
NASA's Calculation of the Total Lunar Eclipse May 26, 2021



NASA's Calculation of the Partial Lunar Eclipse November 19, 2021

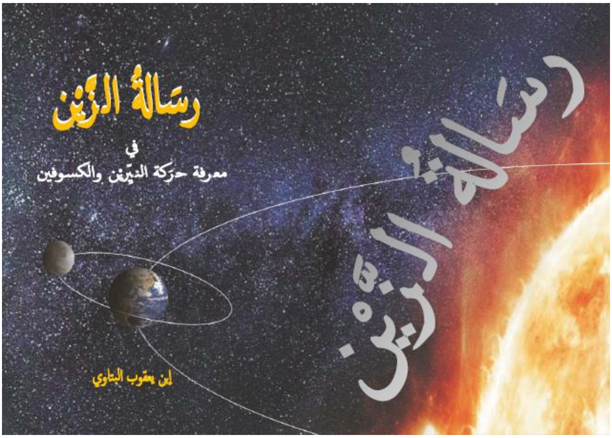


NASA's Calculation of the Total Lunar Eclipse May 16, 2022



Attachment 4

Cover Book *Risālah Az-Zain* by Ibn Ya’qub Al-Batawi



Attachment 5

INTERVIEW RESULT

Interviewee : Ibn Ya'qūb al-Batāwy (penulis kitab *Risālah az-Zain*)

Interviewer : Rohadatul 'Aisy Idra

Via : WhatsApp

Question: Dari mana pengambilan data hisab gerhana bulan dalam buku *Risālah az-Zain* ini pak?

Answer: Beberapa karya mulai dari kitab guru-guru saya hingga Jean Meuss (cetakan kedua) dan lain-lain

Question: Apa saja kitab guru-guru yang Bapak jadikan referensi pak?

Answer: *Irsyadul Murid*, *Durul Aniq*, dan lain-lain.

Question: Disamping kitab *Risālah az-Zain* apakah ada kitab lain yang berkaitan dengan falak yang sudah bapak tulis pak?

Answer: Ada, *Risālah al-Manzilah* yang membahas tentang arah kiblat, waktu sholat, dan pembahasan lintang dan bujur. Kitab *Risālah az-Zain* adalah buku kedua saya.

Question: Setelah saya bandingkan rumus perhitungan Risalah az-Zain dengan Jean Meuss ada perbedaan-perbedaan minor pak. Salah satunya adalah perbedaan penggunaan kalender. Apa alasan bapak menggunakan sistem penanggalan yang berbeda dengan Jean Meeus yang menggunakan Kalender

	Masehi?
Answer:	Saya menggunakan Kalender Hijriyah dalam kitab saya. Kalender Hijriyah digunakan untuk menyesuaikan metode yang lazim dipakai di kalangan Pesantren.
Question:	Perbedaan yang lain yaitu penyederhanaan beberapa rumus dan peniadaan rumus delta T, apa alasan peniadaan rumus delta T dalam kitab bapak?
Answer:	Saya sengaja tidak menggunakan rumus delta T dalam Kitab *Risālah az-Zain* agar hisabnya lebih mudah dipahami oleh pemula.
Question:	Di Kitab *Risālah az-Zain* ada penyederhanan rumus yaitu rumus untuk mencari nilai F dan nilai A, apa alasan penyederhanaan ini pak?
Answer:	Dalam kitab saya tidak ada rumus F1 karena rumus tersebut digabung dengan rumus F agar hasil dari penggabungan rumus tersebut dapat langsung menentukan *imkan* gerhana (mungkin atau tidaknya suatu gerhana dapat terjadi). Rumus C13 (yang ada di hisab Jean Meeus) juga digabung dengan rumus A agar terlihat perbedaan antara rumus dasar dengan rumus koreksi pengaruh planet (nilai A).

Note: This interview is in Bahasa and not translated into English to maintain the originality of the interview.

Attachment 5

ANNOTATION LETTERS

Yang bertandatangan di bawah ini:

Nama	: Ikhwanudin
Tempat, Tanggal Lahir	: Jakarta, 24 Oktober 1992
Umur	: 28
Pendidikan Akhir	: S1
Pekerjaan	: Guru

Menerangkan dengan sebenar-benarnya bahwa saudara:

Nama	: Rohadatul ‘Aisy Idra
NIM	: 1702046108
Fakultas/Jurusan	: Syari’ah dan Hukum
Alamat	: Pondok Pesantren Life Skill Daarun Najaah, Jl. Bukit Beringin Lestari Barat, Kav. C131, Wonosari, Ngaliyan, Semarang.

Benar-benar telah melakukan wawancara kepada guna melengkapi data yang diperlukan untuk menyusun skripsi mahasiswa tersebut dengan judul**: “AN ALGORITHM ANALYSIS OF THE LUNAR ECLIPSE CALCULATION IN THE BOOK RISĀLAH AZ-ZAIN BY IBN YA'QŪB AL-BATĀWY”**

Mengetahui,

Ikhwanudin
(Ibn Ya’qub Al-Batawy)

CURRICULUM VITAE

Full Name : Rohadatul 'Aisy Idra

Place, Date of Birth : Payakumbuh, 11th February 1999

Address : Diponegoro Street, Talang Koto Nan IV, Payakumbuh, West Sumatera.

Contact Number : +6282385882920

E-mail : rohadatulidra@gmail.com

ACADEMIC QUALIFICATIONS

A. Formal Academics
   1. Raudhatul Jannah Elementary School (2006)
   2. Diniyyah Pasia Junior High School (2014)
   3. Diniyyah Pasia Senior High School (2017)
   4. State Islamic University of Walisongo *(ongoing)*
B. Non-Formal Academics
   1. Ella English Course, Pare, Kediri (2018)
   2. Mahesa English Course, Pare, Kediri (2019)
   3. Life Skill Daarun Najaah Boarding School *(ongoing)*
C. Organization Experience
   1. OPBQ of Diniyyah Pasia Boarding School
   2. LPM Justisia
   3. LPM Zenith
   4. UKM JQH El-Fasya
   5. CSSMoRA Walisongo