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Accuracy Analysis of Hilal Calc 3.0 Application in Determining the Beginning of the Kamariah Month

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Abstract: *This study was motivated by the researcher's attention to the numerous applications used to determine the beginning of the Kamariah month. One such application, Hilal Calc 3.0, is notable for its ease of use. Hilal Calc 3.0 is an application that enables the calculation of the beginning of the Kamariah month using the Hilal visibility criteria, which is somewhat antiquated. The objective of the research project is to ascertain the accuracy and feasibility of utilizing the application under investigation. This research employs a literature review with a comparative descriptive approach. The findings of this study indicate that the Hilal Calc 3.0 application is categorized as quite accurate. This is evidenced by the results of calculations using the Hilal Calc 3.0 application, which exhibit a difference of less than five minutes when compared to the calculation using the Ephemeris system, which ranges from 0-4 minutes. The most significant discrepancy between the two is in the hisab results for the beginning of the month of Ramadan 1443 H, namely the elongation of the moon by 0° 4 '57.54". This discrepancy may be attributed to the differing algorithms employed by the Hilal Calc 3.0 application and the Ephemeris system.*
Keywords: *The Beginning of the Kamariah Month, Hilal Calc 3.0, Ephemeris System*

Abstrak: *Penelitian ini dilatarbelakangi oleh perhatian peneliti terhadap banyaknya aplikasi-aplikasi yang digunakan dalam menentukan awal bulan Kamariah. Dan ada salah satu aplikasi yang terbilang sederhana dalam penggunaannya, yaitu Hilal Calc 3.0. Aplikasi Hilal Calc 3.0 adalah aplikasi yang dapat digunakan untuk menentukan perhitungan awal bulan Kamariah menggunakan kriteria visibilitas hilal yang terbilang lawas. Fokus penelitian ini adalah untuk mengetahui keakurasian dan kelayakan aplikasi ini untuk digunakan. Penelitian ini merupakan penelitian kepustakaan dengan pendekatan deskriptif komparatif. Hasil penelitian ini menunjukkan bahwa aplikasi Hilal Calc 3.0 dikategorikan cukup akurat. Hal ini dibuktikan dari hasil perhitungan menggunakan aplikasi Hilal Calc 3.0 yang selisihnya tidak terlalu besar jika dikomparasikan dengan menggunakan perhitungan sistem Ephemeris yaitu berkisar antara 0-4 menit. Perbedaan yang paling signifikan antara keduanya terdapat pada hasil hisab awal bulan Ramadhan 1443 H yaitu pada elongasi bulannya sebesar 0° 4' 57.54". Perbedaan hasil tersebut dapat terjadi dikarenakan faktor algoritma yang digunakan pada aplikasi Hilal Calc 3.0 dan sistem Ephemeris.*
Kata Kunci: *Awal Bulan Kamariah, Hilal Calc 3.0, Sistem Ephemeris.*

A. Introduction

The determination of the beginning of the Kamariah month has significant importance in the Hijri calendar as it marks the start of the Islamic month, impacting the commencement of the Ramadan fast, and the commemoration of Eid al-Fitr and Eid al-Adha.[1] This determination is not

[1]Irfan, "Studi Analisis Terhadap Penentuan Awal Bulan Menggunakan Aplikasi Hilal Calc 3.0," *Skripsi*, 2022. Lihat juga, Ahmad Adib Rofiuddin, "Dinamika Sosial Penentuan Awal Bulan Hijriah Di Indonesia," *Istinbanth, Jurnal Hukum Dan Ekonomi Islam* 18, no. 2 (2019): 233, http://www.istinbath.or.id. Dan lihat juga, Muh Rasywan Syarif, "Implementasi Formulasi Kalender Islam Internasional Pasca Mukhtamar Turki 2016," *Elfalaky* 3, no. 1 (2019): 95–122, https://doi.org/10.24252/ifk.v3i1.14133. dan lihat juga, Nihayatur Rohmah, "Diskursus Kalender Hijriyah Global

only linked to worship but also encompasses the social and cultural activities of the Muslims. For instance, the onset of Ramadan influences the fasting schedule, tarawih prayers, and other key dates in the given month. That underscores the importance of precision and clarity in establishing the start of the Kamariah month.[2]

In order to enhance the accuracy and consistency of determination at the beginning of the Kamariah month, modern technology has become an integral part of this process.[3] One widely used tool is software applications designed to predict the positions of the new moon and establish the start of the month based on astronomical calculations. In this context, the researcher focuses on a specific application, specifically the *Hilal Calc 3.0* application. This application allows users to estimate the appearance of the hilal using several criteria, including Odeh 2005, Istanbul 1978, Malaysia 1992, and Malaysia 2013 unofficial criteria. Therefore, this study aims to conduct a comprehensive evaluation of the *Hilal Calc 3.0* application's accuracy in determining the beginning of the Kamariah month.

This research will also involve a comparison with another method, the Ephemeris Hisab Rukyat calculation system. This method relies on more complex astronomical calculations and systematically considers factors such as the position of the Earth, Sun, and Moon. By combining modern and traditional technological approaches, this research aims to provide an understanding of the accuracy of the *Hilal Calc 3.0* application in determining the beginning of the Kamariah month.

B. Method

This research is of the library research, employing a comparative descriptive approach. Researchers used this method to determine the accuracy and feability of the *Hilal Calc 3.0* application in determining the beginning of the Kamariah month, which was then compared with the Ephemeris system. The sources and type of data utilized include the *Hilal Calc 3.0* application, with several books and articles from journals that align with the research theme. The data collection techniques employed are literature study and documentation.

Pasca Kongres Istambul Turki 2016," *Justicia Islamica* 14, no. 2 (2017): 107–24, https://doi.org/10.21154/justicia.v14i2.1224. Dan lihat juga, Ahmad Fauzan, "Penetapan Awal Bulan Qamariyah Dalam Perspektif Maqashid Al-Shari'ah," *Jurnal Hukum Islam* 16 (2018): 18–32, https://doi.org/10.28918/jhi.v16i1.1301.

[2]Amirah Himayah Husna, "Unifikasi Kalender Hijriah Nasional Menurut Perspektif Muhammadiyah Dan Nahdlatul Ulama," *AL - AFAQ : Jurnal Ilmu Falak Dan Astronomi* 4, no. 1 (2022): 1–19, https://doi.org/10.20414/afaq.v4i1.4169.

[3]Encup Supriatna, *Integrasi Sosial Umat Islam Indonesia melalui Hisab dan Rukyat yang Terintegratif (Menebar Gagasan Baru Guru Besar UIN Sunan Gunung Djari Bandung untuk Peradaban Dunia)*, cet I, (Bandung: Bimedia Pustaka Utama, 2022), 113.

C. Result and Discussion

1. Overview of *Hilal Calc 3.0* Application

Hilal Calc 3.0 is a simple application used to determine the visibility of the new moon after sunset, which is then used to determine the beginning of the next Hijri month. This application is specially designed for rukyatul hilal purposes and comes with ephemeris data to facilitate observation activities. Released on December 28, 2015, *Hilal Calc 3.0* was last updated on February 25, 2017. The app was developed by AT Inc. from Malaysia and is available for free on the Play Store. With over five thousand downloads, the app has a rating of 4.6 out of 5.

The *Hilal Calc 3.0* application has several menus on the main screen, which are relatively few, including:[4]

a. Location Menu: This menu aims to identify the user's location before calculating hilal visibility. The positioning uses the GPS (Global Positioning System) already installed on the user's smartphone. By pressing the location symbol, the application will automatically determine the user's coordinates (latitude and longitude), GMT (Greenwich Mean Time), and address. However, this menu functions correctly only after the user activates the location feature on their smartphone.

b. Data Menu: This menu displays information about the calculation results done by the user. It includes the user's latitude and longitude coordinates, details of the new moon's time based on specific criteria, and data on the positions of the Sun and Moon calculated for the new moon entry.

c. Other Menu: This menu includes: Manual Location Setting: Users can manually enter the location name, latitude, longitude, and GMT. Share Data: The current menu is experiencing technical difficulties (bugs) preventing proper use. Term Description: This section explains the terms used in the application. About: Contains information about the application version and developer email. Check Update: Allows users to check for available application updates.

d. Month, Year, and Criteria Menu: This menu is used to select the month and year for calculating the beginning of the month and determine the criteria to use. At the bottom, over there is an EXE button (execute) to obtain the calculation results. To the left of the EXE button, there is an arrow button used to change the visibility criteria.

2. Operation of Hilal Calc 3.0 App

Using the *Hilal Calc 3.0* application to determine the beginning of the Kamariah month is relatively simple because part of the process is possible automatically. Here is how to use it**:**

[4]Irfan, "Studi Analisis Terhadap Penentuan Awal Bulan Menggunakan Aplikasi Hilal Calc 3.0.", 12.

a. The *Hilal Calc 3.0* application may be downloaded and installed free of charge from the Google Play Store.
b. Ensure that the mobile data connection (internet) is on so that the GPS on your smartphone device is active. Upon launching the application, the user will be presented with a display of the latitude and longitude coordinates of their current location, accompanied by the local time zone. If this information does not appear, tap the location button in the top menu.

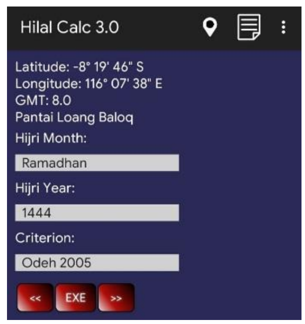

Image 2.1 The Initial Display of the Hilal Calc 3.0 App

c. Specify the Hijri month and year you wish to calculate, as well as the Hilal visibility criteria you want to use. Then, press the "EXE" button to view the calculation results. The application will display astronomical data of the Moon and Sun relevant to the Rukyatul Hilal process and show the status of hilal visibility based on the selected criteria.

Image 2.2 Hisab Result of the Beginning of Ramadan 1444 H

3. Accuracy of Determination of the Beginning of the Kamariah Month with *Hilal Calc 3.0* Application

Researchers tested the calculation of the beginning of certain months—Ramadan, Shawwal, and Dhulhijjah 1443 H—using the rukyatul hilal markaz coordinates on Lombok Island (Loang Baloq Beach, Mataram). They compared the results of calculations using the *Hilal Calc 3.0* application with calculations using the Ephemeris system. Here are the results:

a. The beginning of Ramadan 1443 H

1) *Hilal Calc 3.0* application

Observation for determining the start of Ramadan 1443 H can be done on April 1, 2022, using the *Hilal Calc 3.0* application. The hilal visibility status on that date is as follows:

a) Odeh 2005 criteria: visible only with optical aid
b) Istanbul 1978 criteria: visible
c) Malaysia 1992 (Wujudul Hilal) criteria: visible.

Image 3.1 Hisab Data for the Beginning of Ramadan 1443 H Using Hilal Calc 3.0 Application

2) Ephemeris system[5]

a) Calculation for Loang Baloq Beach location, Mataram, NTB with position:

Latitude of the place (φ) = -8° 36’ 9.6”
Longitude of the place (λ)= 116° 4’ 25,5”
Height = 4 meters above the sea level

I. Converting Dates

29 Sha’ban 1443 H

time that has passed 1442 year, and 7 months, and 29 days

1442 years ÷ 30 years = 48 cycles and 2 years

48 cycles	= 48 x 10.631 days	=	510.288 days
2 years	= 2 x 354	=	708 days
7 months	= (30 x 4) + (29 x 3)	=	207 days

[5]Kementerian Agama Republik Indonesia, *Ephemeris 2022*, 2021.

29 days = 29 days +
Total = 511.232 days
Difference between the Gregorian and Hijri calendar = 227.016 days
Gregory's new account = 13 days +
Total = 738.261 days
511.232 ÷ 7 = 73.033 and 1 = Friday (counted from Friday)
511.232 ÷ 5 = 102.246 and 2 = Pahing (counted from Legi)
738.261 ÷ 1461 = 505 cycles and 456 days
505 cycles = 505 x 4 = 2020 year
456 days = 1 year and 91 days
Time passed = 2021 year + 3 months + 1 days
As a result, 29 Sha'ban 1443 AH coincides with April 1, 2022 AD (Friday Pahing).

II. The smallest FIB (Moon Illumination Fraction) on April 1, 2022 AD is 0.00089, at 7 (UT)

III. ELM 7 = 11° 32' 32"
ELM 8 = 11° 34' 60" –
Difference (B_1) = 00° 02' 28"

IV. ALB 7 = 11° 49' 04"
ALB 8 = 12° 21' 46" –
Difference (B_2) = 00° 32' 42"

V. ELM 7 = 11° 32' 32"
ALB 7 = 11° 49' 04" –
MB = -00° 16' 32"

VI. Calculating Sabak Bulan Mu'addal (SB) with the formula $SB = B_2 - B_1$
B_2 = 00° 32' 42"
B_1 = 00° 02' 28" –
SB = 00° 30' 14"

VII. Ijtima' point = MB ÷ SB = -00° 16' 32" ÷ 00° 30' 14"
= -00° 32' 48.68"

VIII. Smallest FIB time = $07^j\ 00^m\ 00^d$
Ijtima' point = -00° 32' 48.68" +
Ijtimak = $06^j\ 27^m\ 13.32^d$
Correction ΔT = $00^j\ 02^m\ 11.043^d$ –
Ijtimak in UT = $06^j\ 25^m\ 0.397^d$
Koreksi WITA = $08^j\ 00^m\ 00^d$ +
Ijtima' = $14^j\ 25^m\ 0.397^d$

Formula $\Delta T = (102.3 + 123.5 \times t + 32.5 \times t^2) \div 3600$ (J. Meeus)

T = (year – 2000) ÷ 100 = (2022 – 2000) ÷ 100 = 0.22

IX. Approximate Sunset at Loang Baloq Beach, Mataram, NTB on 1 April 2022 AH (29 Sha'ban 1443 AH)

φ = -8° 36’ 9.6” λ = 116° 4’ 25,5” Height = 4 meters
δ (10 UT) = 4° 36’ 33” e (10 UT) = -3m 52s
Dip = √4 x 0.0293 = **00° 03’ 30.96”**
h = -(00° 16’ + 00° 34’ 30” + Dip) = -00° 54’ 0.96”
cos t = -tan φ tan δ + sin h ÷ cos φ ÷ cos δ
= -tan -8° 36’ 9.6” tan 4° 36’ 33” + sin -00° 54’ 0.96” ÷ cos -8° 36’ 9.6” ÷ cos 4° 36’ 33”
= -0.00374597499823
t = 90° 12’ 52.66”
12 – e = $12^j\ 03^m\ 52^d$
t ÷ 15 = $\underline{06^j\ 0^m\ 51.51^d}$ +
12 – e + t ÷ 15 = $18^j\ 04^m\ 43.51^d$
λ ÷ 15 = $\underline{07^j\ 44^m\ 17.7^d}$ –
Sunset = $10^j\ 20^m\ 25.81^d$

X. Data from Ephemeris at $10^j\ 20^m\ 25.81^d$ (UT)

i. Apparent Declination (δ_o)
δ_o jam 10 = 4° 36’ 33” δ_o jam 11 = 4° 37’ 31”
Interpolasi = δ_o10 – ((δ_o10 - δ_o11) x c
= 4° 36’ 33” – ((4° 36’ 33” - 4° 37’ 31”) x 00° 20’ 25.81”
= **4° 36’ 52.74”**

ii. Semi Diameter (SD_o)
SD_o10 = 00° 16’ 00.37” SD_o11= 00° 16’ 00.36”
Interpolasi = SD_o10 – ((SD_o10 - SD_o11) x c
= 00° 16’ 00.37” – ((00° 16’ 00.37” - 00° 16’ 00.36”) x 00° 20’ 25.81” = **00° 16’ 0.366”**

iii. Equation of Time (e)
e 10 = -3m 52d e 11 = -3m 52d
Interpolation= e10 – ((e10 – e11) x c
= -3m 52d – ((-3m 52d – (-3m 52d) x 00° 20’ 25.81”
= **-3m 52d**

iv. Calculating the Sun's Height with the formula:
h_o = -(SD_o + 00° 34’ 30” + Dip)
= -(00° 16’ 0.366” + 00° 34’ 30” + 00° 03’ 30.96”)
= **-00° 54’ 1.326”**

v. Calculating the Sun Hour Angle with the formula:

Cos t_o = -tan φ tan δ + sin h ÷ cos φ ÷ cos δ

= -tan -8° 36’ 9.6” tan 4° 36’ 52.74” + sin -00° 54’ 1.326” ÷ cos -8° 36’ 9.6” ÷ cos 4° 36’ 52.74”

= -0.00373332592795

t_o = **90° 12’ 50.05”**

vi. Calculating the time of Sunset (Ghurub) with the formula:

Ghurub = 12 – e + (t_o ÷ 15) – (λ ÷ 15) + 8^j

= 12 – (-3m 52d) + (90° 12’ 50.05” ÷ 15) – (116° 4’ 25.5” ÷ 15) = $10^j20^m25.6^d$ + 08^j = **$18^j20^m25.6^d$**

vii. Calculating the Sun's Rectangular Asensio by interpolation:

AR_o 10 = 10° 43’ 03” AR_o 11= 10° 45’ 20”

Interpolation = AR_o10 – ((AR_o10 - AR_o11) x c

= 10° 43’ 03” – ((10° 43’ 03” - 10° 45’ 20”) x 00° 20’ 25.6”

= **10° 43’ 49.6”**

viii. Calculating the Moon's Rectangular Asensio by interpolation:

$AR_($ 10 = 13° 39’ 23” $AR_($ 11 = 14° 08’ 33”

Interpolation = $AR_($10 – (($AR_($10 – $AR_($11) x c

= 13° 39’ 23” – ((13° 39’ 23” - 14° 08’ 33”) x 00° 20’ 25.6”

= **13°49’ 18.7”**

ix. Calculating the Declination of the Moon

$\delta_($ 10 = 02° 16’ 32” $\delta_($ 11 = 02° 31’ 13”

Interpolation = $\delta_($10 – (($\delta_($10 - $\delta_($11) x c

= 02° 16’ 32” – ((02° 16’ 32” - 02° 31’ 13”) x 00° 20’ 25.6”

= **02° 21’ 31.9”**

x. Calculating the Semi Diameter ($SD_($)

$SD_($ 10 = 00° 15’ 26.88” $SD_($ 11 = 00° 15’ 26.50”

Interpolation = $SD_($10 – (($SD_($10 - $SD_($11) x c

= 00° 15’ 26.88” – ((00° 15’ 26.88” - 00° 15’ 26.50”) x 00° 20’ 25.6” = **00° 15’ 26.75”**

xi. Calculating the Horizontal Parallax of the Moon

$HP_($ 10 = 00° 56’ 41” $HP_($ 11 = 00° 56’ 40”

Interpolation = $HP_($10 – (($HP_($10 - $HP_($11) x c

= 00° 56’ 41” – ((00° 56’ 41” - 00° 56’ 40”) x 00° 20’ 25.6”

= **00° 56’ 40.65”**

xii. Calculating the Moon Hour Angle

$t_($ = AR_o – $AR_($ + t_o

= 10° 43’ 49.6” - 13°49’ 18.7” + 90° 12’ 50.05”
= **87° 7’ 20.95”**

xiii. Calculating the true hilal height

Sin $h_{(}$ = sin φ sin $\delta_{(}$ + cos φ cos $\delta_{(}$ cos $t_{(}$
= sin -8° 36’ 9.6” sin 02° 21’ 31.9” + cos -8° 36’ 9.6” cos 02° 21’ 31.9” cos 87° 7’ 20.95”
= 0.0434376230674 = **02° 29’ 22.47”**

xiv. Calculating the Parallax of the Moon

$P_{(}$ = cos $h_{(}$ x $HP_{(}$
= cos 02° 29’ 22.47” x 00° 56’ 40.65” = **00° 56’ 37.44”**

xv. Calculating the hilal height

$h_{(}^{o}$ = $h_{(}$ - $P_{(}$ + $SD_{(}$
= 02° 29’ 22.47” - 00° 56’ 37.44” + 00° 15’ 26.75”
= **01° 48’ 11.78”**

xvi. Calculating refraction

Refr = 0.01695 ÷ tan ($h_{(}^{o}$ + 10.3 ÷ ($h_{(}^{o}$ + 5.1255))
= 0.0169 ÷ tan (01° 48’ 11.78” + 10.3 ÷ (01° 48’ 11.78” + 5.1255))
= **00° 17’ 41.55”**

xvii. Calculating the mar’i hilal height

$h_{(}$’ Upper edge = $h_{(}^{o}$ + Refr + Dip
= 01° 48’ 11.78” + 00° 17’ 41.55” + 00° 03’ 30.96” = **02° 09’ 24.29”**

$h_{(}$’ centre = $h_{(}$’$_{\text{upper edge}}$ – $SD_{(}$
= 02° 09’ 24.29” - 00° 15’ 26.75”
= **01° 53’ 57.54”**

xviii. Calculating the *Nisful Fudlah* of the Moon

Sin NF = (sin φ sin $\delta_{(}$) ÷ (cos φ cos $\delta_{(}$)
= (sin -8° 36’ 9.6” sin 02° 21’ 31.9”) ÷ (cos -8° 36’ 9.6” cos 02° 21’ 31.9”)
= -0.00623184219663

NF = **-0° 21’ 25.41”**

xix. Calculating the Parallax *Nisful Fudlah* of the Moon

PNF = cos NF x $HP_{(}$
= cos -0° 21’ 25.41” x 00° 56’ 40.65”
= **00° 56’ 40.58”**

xx. Calculating the Half-Noon Arc of the True Moon

SBSH = 90° + NF

= 90° + (-0° 21’ 25.41”) = **89° 38’ 34.59”**

xxi. Calculating the Half-arc of the Noon Moon

SBS = 90° + NF + PNF – ($SD_{(}$ + 0.575 + Dip)
= 90° + (-0° 21’ 25.41”) + 00° 56’ 40.58” – (00° 15’ 26.75” + 0.575 + 00° 03’ 30.96”) = **89° 41’ 47.44”**

xxii. Calculating the Length of Hilal on the horizon (Lag)

$Lm_{(}$ = (SBS – $t_{()}$ ÷ 15
= (89° 41’ 47.44” - 87° 7’ 20.95”) ÷ 15
= **$00^j\ 10^m\ 17.766^d$**

xxiii. Calculating the Moonset Time

$Set_{(}$ = Ghurub + $Lm_{(}$
= $18^j 20^m 25.6^d + 00^j\ 10^m\ 17.766^d$
= **$18^j 30^m 43.366^d$**

xxiv. Calculating the azimuth of the sun

Tan A_o = -sin φ ÷ tan t_o + cos φ tan δ_o ÷ sin t_o
= -sin -8° 36’ 9.6” ÷ tan 90° 12’ 50.05” + cos -8° 36’ 9.6” x tan 4° 36’ 52.74” ÷ sin 90° 12’ 50.05”
= 0.07924946567456
= 4° 31’ 52.28” + 270° = **274° 31’ 52.28”**

xxv. Calculating the azimuth of the Moon

Tan $A_{(}$ = -sin φ ÷ tan $t_{(}$ + cos φ tan $\delta_{(}$ ÷ sin $t_{(}$
= -sin -8° 36’ 9.6” ÷ tan 87° 7’ 20.95” + cos -8° 36’ 9.6” x tan 02° 21’ 31.9” ÷ sin 87° 7’ 20.95”
= 0.0482997528868

$A_{(}$ = 02° 45’ 54.8” + 270° = **272° 45’ 54.8”**

xxvi. Calculating the Position of the Hilal (difference between the azimuth of the Moon and the Sun)

PH = $A_{(}$ - A_o
= 02° 45’ 54.8” - 4° 31’ 52.28”
= **01° 45’ 57.48”**

xxvii. Calculating the Moon Illumination Fraction

FI jam 10 = 0.00107 FI jam 11 = 0.00121

Interpolasi = FI10 – ((FI10 – FI11) x c
= 0.00107 – ((0.00107 – 0.00121) x 00° 20’ 25.6”
= 0.001117662 x 100% = 0.11%

xxviii. Calculating the Width of Nurul Hilal

NH = (√[PH^2 + $h_{(}'^2$] ÷ 15

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= (√[(-01° 45’ 57.48”)^2 + (02° 09’ 24.29”)^2]) ÷ 15
= (√[3° 7’ 7.09” + 04° 39’ 5.61”]) ÷ 15
= (√07° 46’ 12.7”) ÷ 15
= 02° 47’ 15.024” ÷ 15 = **0.1858337 Radius**

xxix. Calculating Elongation
Cos E = cos h(’$_{\text{Upper edge}}$ x cos PH
= cos 02° 09’ 24.29” x cos 01° 45’ 57.48”
= **02°47’ 14.074”**

xxx. Calculating the age of the hilal
Age of Hilal = Sunset – Ijtima’
= 18^{j}20^{m}25.6^s - 14^j 25^m 0.397^s
= **3 hours 55 minutes 25.203 seconds**

Based on the series of calculations above for the same research location, the beginnings of the months of Shawwal and Dhulhijjah, as well as those of other months, can also be determined. However, this study focuses only on three months: the start of Ramadan, Shawwal, and Dhulhijjah. The difference between each month lies in data such as the Sun's declination value, equation of time, and other information available in the annual Ephemeris Hisab Rukyat book published by the Ministry of Religious Affairs of the Republic of Indonesia. Below are the results of the calculations for the beginnings of Ramadan, Shawwal, and Dhulhijjah using the Hilal Calc 3.0 application, which will be compared with the calculations from the Ephemeris system.

Table 3.1 Difference between Sun and Hilal Data for the Beginning of Ramadan 1443 AH Hilal Calc 3.0 Application and Ephemeris System

	Hilal Calc 3.0	Ephemeris	Difference
Conjunction	14:27:39 WITA	14:25:0.397 WITA	0^j 2^m 38.603^d
Sunset	18:20:18 WITA	18:20:25.6 WITA	0^j 2^m 38.603^d
Moonset	18:28:46 WITA	18:30:43.36 WITA	0^j 2^m 38.603^d
Moon Altitude	1° 49’	1° 53’ 57.54”	0° 4’ 57.54”
Elongation	2° 43’	2° 47’ 14.074”	0° 4’ 14.074”
Moon Azimuth	272° 47’ 33”	272° 45’ 54.8”	0° 1’ 38.2”
Sun Azimuth	274° 32’ 37”	274° 31’ 52.28”	0° 0’ 44.72”
Azimuth Difference	1° 45’	1° 45’ 57.48”	0° 0’ 57.48”
Moon Age	3^j 52^m 38^d	3^j 55^m 25.203^d	0^j 2^m 47.203^d
Visible Duration	0^j 8^m 28^d	0^j 10^m 17.766^d	0^j 1^m 49.766^d
Moon Phase	0.03%	0.11%	0.08%

Moon Semi-Diamter	0° 15’ 27”	0° 15’ 26.75”	0° 0’ 0.25”

Table 3.2 Difference between Sun and Hilal Data for the Beginning of Syawal 1443 AH Hilal Calc 3.0 Application and Ephemeris System

	Hilal Calc 3.0	**Ephemeris**	**Difference**
Conjunction	04:30:44 WITA	4:28:51.027 WITA	$0^j\ 1^m\ 52.973^d$
Sunset	18:07:18 WITA	18:07:12.46 WITA	$0^j\ 0^m\ 5.54^d$
Moonset	18:26:56 WITA	18:28:47.16 WITA	$0^j\ 1^m\ 51.16^d$
Moon Altitude	4° 20’	4° 23’ 4.06”	0° 3’ 4.06”
Elongation	5° 13’	5° 15’ 52.13”	0° 2’ 52.13”
Moon Azimuth	287° 40’ 23”	287° 40’ 17.94”	0° 0’ 5.06”
Sun Azimuth	285° 10’ 52”	285° 10’ 18.35”	0° 0’ 33.65”
Azimuth Difference	2° 30’	2° 29’ 59.59”	0° 0’ 0.41”
Moon Age	$13^j\ 36^m\ 15^d$	$13^j\ 38^m\ 21.433^d$	$0^j\ 2^m\ 6.433^d$
Visible Duration	$0^j\ 19^m\ 55^d$	$0^j\ 21^m\ 21.433^d$	$0^j\ 1^m\ 39.7^d$
Moon Phase	0.32%	0.32%	0.00%
Moon Semi-Diamter	0° 15’ 1”	0° 15’ 0.29”	0° 0’ 0.71”

Table 3.3 Difference between Sun and Hilal Data for the Beginning of Dzulhijjah 1443 AH Hilal Calc 3.0 Application and Ephemeris System

	Hilal Calc 3.0	**Ephemeris**	**Difference**
Conjunction	10:53:25 WITA	10:52:55.57 WITA	$0^j\ 0^m\ 29.43^d$
Sunset	18:07:55 WITA	18:08:15.33 WITA	$0^j\ 0^m\ 20.33^d$
Moonset	18:15:28 WITA	18:17:20.26 WITA	$0^j\ 1^m\ 52.26^d$
Moon Altitude	1° 24’	1° 28’ 13.94”	0° 4’ 13.94”
Elongation	4° 32’	4° 32’ 1.933”	0° 0’ 1.933”
Moon Azimuth	297° 35’ 00”	297° 32’ 55.6”	0° 2’ 4.4”
Sun Azimuth	293° 21’ 32”	293° 21’ 4.88”	0° 0’ 27.12”
Azimuth Difference	4° 13’28”	4° 11’ 50.72”	0° 1’ 37.28”
Moon Age	$07^j\ 14^m\ 30^d$	$07^j\ 15^m\ 19.756^d$	$0^j\ 0^m\ 49.756^d$
Visible Duration	$0^j\ 07^m\ 32^d$	$0^j\ 09^m\ 4.93^d$	$0^j\ 1^m\ 32.93^d$
Moon Phase	0.08%	0.19%	0.11%
Moon Semi-Diamter	0° 14’ 43”	0° 14’ 41.812”	0° 0’ 1.18”

Based on the calculated results for the beginning of the Kamariah month using both the Ephemeris system and the Hilal Calc 3.0 application, there is a difference of up to 4 minutes. The most significant disparity between the two calculations lies in the hilal height at the beginning of the Ramadan, which is 0° 4' 57.54". Such differences in results may stem from human error or technical factors. Nonetheless, the variation between the Hilal Calc 3.0 application and the Ephemeris Calculation remains within a reasonable range, indicating that it is one of the simply accurate applications for determining the start of the Hijri month.

D. Conclusion

Hilal Calc 3.0 is a simple application used to determine the visibility of the new moon after sunset, which is then used to determine the beginning of the next Hijri month. This application is specially designed for rukyatul hilal purposes and comes with ephemeris data to facilitate observation activities. The app was developed by AT Inc. from Malaysia. The Hilal Calc 3.0 application is a highly accurate tool for calculating the beginning of the Kamariah month, after comparing it with the calculation results of the Ephemeris system. The difference shown is in the range of 0-4 minutes. The most significant difference is in the hisab of the beginning of the month of Ramadan 1443 H, which is 0° 4’ 57.54”. Nonetheless, the variation between the Hilal Calc 3.0 application and the Ephemeris Calculation remains within a reasonable range, indicating that it is one of the simply accurate applications for determining the start of the Hijri month.

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