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General Astronomical Data on the Orbit of the Full Moon / Nisfhu Night Corresponding to May, Celebrated as the Waisak New Year

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A R T I C L E I N F O

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A B S T R A C T

This scientific paper aims to design a simple astronomical teaching aid illustrating the Moon's orbital path, made of pralon, so that it can be used to compile the Nishfu table. Nishfu is defined as the midpoint or median; in this context, the natural numbers from 1 to 29 represent the Moon's orbital numbers, so the median or nishfu is the 15th number in the sequence. The orbital numbers 1 through 29 correspond to the actual physical appearance of the Moon's reflected light where the true source of light is the Sun as follows: the 1st orbit represents the first crescent moon (1–3% brightness), the 2nd orbit represents the second-day crescent moon (3–6% brightness), and so on, with the 14th orbit representing the full moon (100% brightness), finally the 28th phase as the waning crescent (3–1% brightness), and the 29th phase as the dark moon (0% brightness) in the Hijri calendar. Theoretically, the interval from 1 to 29 can be expressed as 15 ± 14, with 15 representing the median (nishfu) or midpoint between 1 and 29; thus, the night of nishfu is the midpoint of the Hijri calendar month. In everyday life, generally every full moon (the 14th phase) is considered the night of nishfu. By convention, the nishfu night in May of the solar-based Gregorian calendar marks the full moon (the 14th lunar phase) and is celebrated as the Vesak New Year according to Buddhist teachings.

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INTRODUCTION

Design is a form of skill or expertise that produces products, whether in the form of prototypes or small-scale models, full-scale or standard-sized items, or even software. Therefore, this expertise is applied in various fields, including politics, economics, society, and culture, as well as science and technology—for example, government design and development, the design and development of the people's economy, language laboratory design and development, housing construction design and development, waste treatment design and development, the design and development of plant-fertilizing microorganism cultivation, and so on.

Essentially, design and development skills are intended to monitor the progression of a phenomenon under study. The Lunar Orbit Design and Development (TRB) is a device or unit used to observe the Moon so that the angular degree between the Moon's and the Sun's positions can be read or monitored from the observation site. To design the TRB, one must first accept the existing and still-valid conventions established by earlier scientists, such as the angle of the great circle being 360°, the duration of one orbital cycle from sunset to the next sunset being 24 hours, and one hour being equivalent to 60 minutes, so that one degree is equivalent to four minutes (Purcell and Varberg, 1996).

The convention for determining the start of the Hijri calendar month (the first orbit) is when the Moon is visible on the western horizon at a specific angular interval at Maghrib (sunset); in this configuration, the Moon's reflection appears crescent-shaped (Febi and Tiryono, 2008).

The work of designing the TRB essentially involves mapping or plotting observational data on the duration of the Sun's and Moon's paths on a Cartesian plane. Therefore, observations of these phenomena must first be conducted. Field observations are carried out to obtain a coherent record of a phenomenon. The information derived from these observations is referred to as observational data. Furthermore, observational data serve as the primary elements for designing the TRB. The design can be visualized after plotting the observational data on a Cartesian plane, specifically, a two-dimensional Cartesian coordinate system.

Generally, observational data are categorized into two types: probabilistic and deterministic. Probabilistic data is characterized by the fact that the data obtained from observations is non-periodic (fluctuating), whereas deterministic data consists of observational data that exhibits periodic trends. In this study, observing the duration of the Sun's and Moon's paths, the data obtained exhibit a periodic trend, thus indicating a deterministic data set (Tiryono, 2007).

Visually, the paths of the Sun and Moon as seen from the Earth's surface constitute a system; in this case, the system of the Sun's and Moon's orbital paths. A problem that will arise in the future regarding these orbital durations is how long the determination of the Sun's and Moon's orbital durations will remain valid in relation to the correspondence between the Gregorian and Hijri

calendars. Another issue is the need to mathematically analyze the possibility that the Sun's orbital duration might become longer than usual.

Advances in science and technology offer hope for solutions to problems that have arisen in daily life (problem-solving) and for preventing the recurrence of the same problems in the future or the emergence of new ones. These efforts are expected to help resolve problems by drawing on scientific principles as a foundation. Ultimately, these efforts are for the common good, particularly as they relate to the natural phenomenon of the correspondence between the paths of the Sun and the Moon.

The basic mathematics used to design the TRB includes angle measurement, algebra, mapping in the Cartesian coordinate plane, arithmetic operations (+, -, ×, ÷) on real numbers, linear equations, derivatives/rates, and trigonometry (Purcell and Varberg, 1996; Kreyszig, 1988). Angle Measurement is used to observe and measure the angle of the Moon relative to the horizon at sunset using a protractor. Al-Jabar developed equations so that the relationship between the paths of the Sun and the Moon can be expressed in simple linear equations.

The study of Cartesian coordinates is used for mapping or projecting the paths of the Sun and Moon onto a flat plane; arithmetic operations are used for calculations, making it easier to compile a database of observation results; linear equations are used to plot the time intervals of the Sun's and Moon's paths so they can be visualized as function graphs; the study of derivatives is used to calculate the speed of the Sun's and Moon's respective paths from the observation location, and technological advancements have brought convenience, so that in the future, the sensitivity of this simple TRB design will be enhanced through a hybrid mechatronic (mechanical and electronic) system, allowing it to be monitored via a USB connection. With a positive mindset, we can trace the natural phenomena of the Sun's and Moon's paths and see that even before the Gregorian calendar was introduced, a calendar based on the Sun's path had already been in use for thousands of years before the Common Era. Similarly, before the Hijri calendar was established, a calendar based on the Moon's path had already been in use for thousands of years before the Common Era.

LITERATURE REVIEW

The trigonometric (sine) function is used to measure the brightness of the moon's light and to monitor the angular position of the moon. The TRB is easy to design without compromising expected performance when compared to modern, expensive equipment such as the telescopes used at the Bosca-Lembang Planetarium in Bandung. In the long term, mathematical modeling of the Moon's brightness offers a means of determining 1% brightness (young crescent Moon), 50% brightness (first-quarter Moon), 80% brightness (young gibbous Moon), 100% brightness (full Moon), 0% (new Moon), and other brightness percentages that hold sacred or spiritual significance and are commemorated.

For example, in the community of Mecca, observing the Moon's 80% brightness during the month of Dhu al-Hijjah, which marks the ninth day of the lunar cycle, is a spiritual ritual known as Wukup and is widely recognized as the Eid al-Adha holiday.

METHODOLOGY

TRB Design and Construction Method

a. Projection of the Paths of the Sun and Moon on a Cartesian Plane (wood/plywood)

Some of the steps and data required for trajectory projections include:

1. Prepare the first layer of plywood as a Cartesian plane to map the Sun's counterclockwise path, with each coordinate axis labelled as follows: the south axis is labelled 24/00, the east axis is labelled 06 (sunrise), the north axis is labelled 12, and the west axis is labelled 18 (sunset) (assuming that the duration of one solar cycle from sunset to the next sunset is 24 hours).
2. Prepare a second layer of board or plywood, smaller than the first layer, to serve as a Cartesian plane for mapping the Moon's orbit. Arrange it in a clockwise direction, placing the numbers 0–29 with each number spaced 12.20 degrees apart, starting with the number 0 on the west axis, number 7 on the north axis, numbers 14–15 on the east axis, and number 21 on the south axis.
3. Next, attach the pralon ring to the centre of the two plywood panels using nuts and bolts
4. Data on the Moon's brightness and the Moon's angle relative to the Sun
5. Derive other data from the primary data (angle/lag duration, crescent age)

The tools and materials needed to collect data are a protractor to measure the angle of the Moon relative to the Sun (recommended at sunset). Data on the Moon's brightness can be collected by photographing the Moon (with a camera) or through calculations once a mathematical model has been developed.

The second plywood layer is a projection of the Moon's orbit, arranged clockwise with the numbers 0–29. Next, attach a ring made of pralon to the axis at the center of the two plywood panels. Finally, attach the pendulum to the north axis (number 12) so that the north and south axes form a vertical line aligned with Earth's gravity.

b. How to Assemble and Use the TRB

1. The first layer of board or plywood has a hole drilled in the centre to serve as the axis or centre of a circle, with the circle's diameter representing the Sun's orbital path. Thus, if the watch we are wearing currently shows 12:00 p.m. WIB, the Sun's position is on the north axis marked with the number 12; however, if the watch we are wearing shows 12:00 a.m. WIB, then the Sun's position is at the southern axis marked with the number 24/00. The second layer of plywood has a hole drilled in the centre and is joined to the first layer of plywood with their

axes or centres aligned; since the second layer of plywood is smaller than the first, the orbital path on the first layer is not covered by the second layer. The first layer of plywood is fixed in place, while the second layer can be rotated on its axis. The number 0 on the second layer of plywood represents the Sun. Thus, the number 0 on the second layer can be rotated and aligned according to the time at which the observation is made. The PVC pipe attached to the plywood plate's axis is intended to serve as a Moon pointer, making it more convenient for the user. Therefore, it is recommended that the length of the PVC pipe be greater than the diameter of the first layer of plywood.

2. To observe the Moon's path using the assembled TRB, position the TRB according to the cardinal directions with the western axis facing west and the eastern axis facing east. Ensure that the pendulum bob attached to the northern axis aligns with the southern axis, and position the number 0 on the second layer of plywood to correspond with solar time. Then aim the plastic tube to track the Moon until it becomes visible. By following these steps, the plastic tube also acts as an arrow pointing to the corresponding number on the second layer of plywood; the number aligned with the plastic tube indicates the Moon's path number. If the Moon is not yet visible for tracking and previous data is known, then the Moon's position can be determined.

RESULTS AND DISCUSSION

The consensus among early scientists regarding the mapping of the Earth onto a Cartesian coordinate plane was that a day lasts 24 hours; therefore, the globe is divided into 24 parts. In other words, the entire Earth has 24 time zones, and when mapped onto a Cartesian coordinate plane, it will have 24 intervals along the x-axis and 12 intervals along the y-axis (Figure 1). Consistently, each partition (= 1 hour) is equivalent to 15 degrees, so one degree equals four minutes.

Consequently, the Indonesian archipelago from Sabang (–48 minutes relative to WIB) to Merauke (+132 minutes relative to WIB) spans an interval along the X-axis of 45 degrees, equivalent to 180 minutes (3 hours); thus, the archipelago is divided into three time zones: WIB, WITA, and WIT. The paths of the Sun and Moon, when plotted on a Cartesian coordinate plane, yield ordinate values (e.g., Y) that shift over time, periodically moving from the Tropic of Cancer (22.5 degrees north), toward the center/X-axis (the equator at 0 degrees), toward the Tropic of Capricorn (–22.5 degrees south), back to the center/X-axis, and toward the Tropic of Cancer again, and so on as a system of orbital paths.

The projected path of the Sun from GBU-Center to GBS-Center to GBU takes 365.25 days (1 Gregorian year). For convenience in daily life, it is agreed that 1 year = 365 days, and every four years, one day is added due to the accumulation of 0.25 days per year (this additional day is added to February, which normally has only 28 days, making it 29 days in a leap year). Meanwhile,

the projected lunar path from the center of gbu to the center of gbs to the center of gbu takes 28 days.

The brightness of the Moon's light that we observe is the reflection of sunlight by the Moon (just as a mirror reflects light). The orbits of the Sun and the Moon have different durations, causing the brightness of the Moon's light to change gradually from day to day. The time required from when the Sun and Moon are aligned until the next time they are aligned is 29.5 days (c ≈ 2). The correspondence between the Sun's and Moon's paths is illustrated as Surya and Wulan racing around a circular track, as shown in Figure 2. The race begins at 6:00 PM.

Wulan is slower than Surya, so by the time Surya finishes the first lap, Wulan is lagging behind at the dot-1 marker. This pattern continues; Wulan consistently falls behind with each lap, so that by the 28th lap, Wulan appears to be ahead of Surya, and Wulan is finally overtaken by Surya on the 29.52nd lap (at the 8:10 marker). From this illustration, one cycle—the time it takes for the Sun to travel from sunset on the western horizon at 6:00 p.m. through midnight, sunrise on the eastern horizon, noon, and back to sunset—is 24 hours (one day).

According to the almanac, a duration of 29.52 days is used as the length of a day in one Hijri calendar month. Therefore, one Hijri calendar year is 29.52 × 12 = 354.24 days. The moon's brightness can be observed for 28 days (1%–100%); on the 29th day, the moon is new (0%). The brightness of the first crescent moon (1st phase) is 1–3.5%, the 7th phase is 50–60%, the 14th–15th phase has a brightness of 100%, the 21st phase has a brightness of 60–50%, the 28th phase has a brightness of 3.5–1%, and the 29th phase is the new moon with a brightness of 0%. The mathematical model for the Moon's phase brightness is expressed as f(x) = sin 0.5 x, (00 ≤ x ≤ 3600), where x is converted to h.

$$f(h) = \begin{cases} Sin0{,}5(12{,}86)h, & (1 \le h \le 28) \\ 0 \quad\quad\quad\quad\quad\quad , & (h \ge 29) \end{cases}, \qquad h \text{ is the day/track}$$

Moon brightness function y = f(h)*(100%); Example: 14th day/phase --> f(h) = sin (0.5(12.86)/14) yields f(h) = sin 90° = 1; therefore, y = 100%, so at the 14th phase, the Moon is 100% bright (full moon). Given that the period for one full cycle of the Moon's position is 29.52 days,

Table 1. the Moon's Angle Relative to the Sun Shifts by 3600/29.52 = 12.30 Each Day

Δ≈11.01 days forward;

Strategi dan taktik mengamati fullmoon/malam-nishfu yang terjadi pada bulan Mei ==> Tahun Baru Waisak

*** Malam Nishfu Saban ==> Fullmoon di bulan Shaban ***
Nishfu Shaban + 15 hari ==> Bulan Sabit: 1 Ramadan

Year A.D.	Fullmoon in May WAISAK/VESAK	Malam Nishfu Shaban		Year A.H.
		Fullmoon	Nishfu	
2011	Mei 17	Juli 16	17 Juli	1432
2012	Mei 5	Juli 4	5 Juli	1433
2013	Mei 24	Juni 23	24 Juni	1434
2014	Mei 14 --> Mei-15	Juni 12	13 Juni	1435
2015	Mei 3	Juni 1	2 Juni	1436
2016	Mei 21	Mei 21	22 Mei	1437
2017	Mei 10	Mei 11	12 Mei	1438
2018	Mei 29	April 30	1 Mei	1439
2019	Mei 18	April 20	21 April	1440
2020	Mei 7	April 8	9 April	1441
2021	Mei 26	Maret 28	29 Maret	1442
2022	Mei 16	Maret 17	18 Maret	1443
2023	Mei 5 exclipe	Maret 7	8 Maret	1444
2024	Mei 23	Feb 24	25 Feb	1445
2025	Mei 12	Feb 13	14 Feb	1446
2026	Mei 1 dan Mei 31	Feb 2	3 Feb	1447
2027	Mei 20	Jan 22	23 Jan	1448
2028	Mei 9	Jan 11	12 Jan	1449
2029	Mei 27	Des 31, 2028 Des 20	1 Jan dan 21 Des	1450
2030	Mei 17	Des 9	10 Des	1451
2031	Mei 6	Nov 28	29 Nov	1452
2032	Mei 25	Nov 17	18 Nov	**1453**
2033	Mei 14	Nov 6	7 Nov	**1454**
2034	Mei 3	Okt 26	27 Okt	**1455**
2035	Mei 22	Okt 15	16 Okt	**1456**
2036	Mei 10	Okt 4	5 Okt	**1457**
2037	Mei 28	Sept 26	27 Sept	**1458**
2038	Mei 18	Sept 15	16 Sept	**1459**
2039	Mei 8	Sept 4	5 Sept	**1460**
2040	Mei 26			**1461**
...				...
2074	Mei 11			1497
2075	Mei 29			1498
2076	Mei 18			1499

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and discussion above, the following conclusions can be drawn: One Hijri calendar month is approximately 29.52 days long; the Moon's orbit lags behind the Sun's orbit by approximately 49 minutes each day. The function for lunar brightness, y = f(h)*(100%), where f(x) = sin 0.5 x (00 ≤ x ≤ 3600), with x converted to h, yields:

$$f(h) = \begin{cases} Sin0{,}5(12{,}86)h, & (1 \le h \le 28) \\ 0 \quad\quad\quad\quad\quad\quad , & (h \ge 29) \end{cases}, \textit{ h is the day/track}$$

The Moon's angle relative to the Sun shifts each day by 3600/29.52 = 12.250.

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Research is needed on the necessary and sufficient conditions for the first sighting of the crescent moon as the date 1.

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