# Study of factors affecting the depth of lunar craters using trigonometric

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## Abstract

This study aimed to investigate the depth of lunar craters during the first quarter moon (waxing 8th day) and the last quarter moon (waning 8th day), as well as to examine the effect of the elevation angle on the calculated crater depth during the waning 8th day. Photographs were taken using a Dobsonian telescope connected to a Canon EOS 80D DSLR camera. Image data were collected on October 15, 2025 (waning 8th day) between 02:00–04:30 and on October 29, 2025 (waxing 8th day) between 20:00–21:30. The images were analyzed to determine the lunar radius, shadow length, and crater rim relative to the lunar terminator. Trigonometry and basic mathematical principles were applied to calculate and compare the depths of lunar craters. The results showed that the calculated crater depths from both lunar phases were similar. However, the measurements obtained during the waning 8th day were more accurate than those from the waxing 8th day by 4.16%. In addition, it was found that the elevation angle had a significant effect on measurement error, with increasing elevation angles directly corresponding to greater deviations in the calculated crater depth. Therefore, the elevation angle has a greater influence on the measurement error in calculating lunar crater depth than whether the observation was conducted during the waxing or waning phase of the Moon.

keywords : Lunar crater, Elevation angle, Trigonometric theory

## Introduction

The Moon is the only natural satellite of the Earth and is the most clearly visible celestial object to the naked eye from our planet. Although it may appear as a smooth and beautiful glowing sphere, its surface is characterized by numerous craters. These craters were formed by impacts from meteorites and other celestial bodies billions of years ago, resulting in depressions and fractures that remain clearly visible to this day.

For this reason, the research team developed an interest in studying the depth of lunar craters, as such information can help explain the Moon's physical characteristics and geological history. However, the measurement and calculation of crater depth on the Moon can be influenced by several factors, including the angle of elevation during observation, the angle of sunlight incidence, the characteristics and length of the shadows formed, the position of craters near the terminator (the boundary between light and dark), as well as the observer's skill in measurement.

Therefore, this project aims to investigate the factors affecting the calculated depth of lunar craters, with particular emphasis on the influence of the angle of elevation on calculation error, to obtain more accurate and reliable results.

## Methodology

### 1) Data Collection

A DSLR camera, Canon EOS 80D, was attached to a 10-inch reflecting telescope. The shutter speed (SS) and ISO were adjusted as follows: for the 8th day of the waning phase, SS was set to 1/125 and ISO to 500; for the 8th day of the waxing phase, SS was set to 1/2000 and ISO to 4000. Photographs of the Moon were then taken on October 15, 2025 (waning 8th day) and October 29, 2025 (waxing 8th day).

### 2) Data Analysis

2.1 The lunar images were analyzed by determining the center of the Moon using the chord method. Chords were drawn along the illuminated of the Moon, and perpendicular bisectors were constructed from the midpoints of each chord. The intersection of these bisectors was used to locate the center, from which the radius and the central axis of the Moon were determined. The images were then further analyzed.

2.2 The lunar phase data were analyzed using Stellarium. The angle between the observer and a lunar mountain ($\theta$) was calculated using Equation (1), and the angle between the Sun and a lunar crater ($\Phi$) was determined using Equation (2)

$$\theta = \sin^{-1}\left(\frac{D}{R}\right) \quad \text{-----(1)}$$

when D is the distance from the central axis (midline) to the edge of the crater.

R is the radius of the Moon.

and $$\Phi = \alpha + \theta \quad \text{-----(2)}$$

when $\alpha$ is the phase angle of the Moon.

$\theta$ is the angle between the observer and the lunar crater.

2.3 The lunar craters in the photographs were identified using data from Virtual Moon Atlas (VMA).

2.4 The depth of the craters was determined by first calculating the crater diameter in kilometers (km) from standard lunar images. This was done by finding the ratio between the measured lunar radius (R) in centimeters (cm) and the actual lunar radius in kilometers (km). The ratio was then used to convert the measured crater diameter from centimeters (cm) to kilometers (km).

2.5 The shadow length was determined in kilometers (km) using magnified lunar images. The crater diameter was measured in centimeters (cm) from the magnified images to establish the ratio between the measured diameter (cm) and the actual diameter (km). This ratio was then used to convert the measured shadow length from centimeters (cm) to kilometers (km).

2.6 The depth of the lunar craters was analyzed using Equation (3) and compared with the crater depth obtained from Virtual Moon Atlas (VMA).

$$H = \frac{L}{(tan\phi)(cos\theta)} \quad \text{------(3)}$$

When H is the depth of the lunar crater (km).

L is the shadow length of the lunar crater (km).

Φ is the angle between the Sun and the lunar crater.

θ is the angle between the observer and the lunar crater.

2.7 The percentage error (%) was analyzed using Equation (4)

$$\text{Error} = \frac{h}{H} \times 100 \quad \text{-----(4)}$$

When **Error** is the percentage error (%).

**h** is the calculated depth of the lunar crater (km).

**H** is the actual depth of the lunar crater (km), referenced from Virtual Moon Atlas (VMA).

## Result and Discussion

**1) Results of the Study on Lunar Crater Depth on the 8th Day of the Waning and Waxing Phases**

**Table1** Comparison of lunar crater depths on the 8th day of the waning phase and the 8th day of the waxing phase

| Lunar Crater Names (Waning Phase) | h (calculated) | H (actual) | Error (%) | Lunar Crater Names (Waxing Phase) | h (calculated) | H (actual) | Error (%) |
|---|---|---|---|---|---|---|---|
| Copernicus | 2.28 | 3.80 | 40.00 | Aliacensis | 2.50 | 3.7 | 32.16 |
| Reinhold | 3.80 | 3.00 | 26.67 | Albategnius | 4.39 | 4.4 | 0.23 |
| Lansberg | 4.11 | 3.10 | 32.58 | Aristoteles | 4.74 | 3.3 | 43.64 |
| Bulliadus | 5.26 | 3.30 | 59.39 | Agrippa | 2.30 | 3.1 | 28.13 |
| Gauricus | 2.89 | 2.70 | 7.04 | La caille | 2.15 | 2.8 | 23.21 |
| Porter | 2.87 | 2.50 | 14.8 | Manilius | 4.41 | 3.05 | 44.59 |
| Clavious | 4.12 | 3.50 | 17.71 | Nonius | 2.11 | 3.0 | 29.67 |
| Rutherfurd | 3.38 | 2.40 | 40.83 | Walther | 2.68 | 4.10 | 34.63 |
| Average Error (%) | | | 25.37 | Average Error (%) | | | 29.53 |

From the study of lunar crater depths on the 8th day of the waning phase and the 8th day of the waxing phase, it was found that on the waning phase, Gauricus and Bullialdus exhibited the lowest and highest percentage errors, respectively. Meanwhile, on the waxing phase, Albategnius and Manilius showed the lowest and highest percentage errors, respectively. The results also indicated that the average percentage error for the waning phase was 25.37%, which is lower than that of the waxing phase at 29.53%. This demonstrates that determining lunar crater depth during the waning phase yields results that are approximately 4.16% more accurate than those obtained during the waxing phase.

**2) Results of the Study on the Relationship between Angle of Elevation and Error in Calculating Lunar Crater Depth**

**Table2** Comparison of lunar crater depths on the 8th day of the waning phase with different angles of elevation

| Lunar Crater Names | Alt = 35° | | | Alt = 40° | | | Alt = 45° | | |
|---|---|---|---|---|---|---|---|---|---|
| | h (calculated) | H (actual) | Error (%) | h (calculated) | H (actual) | Error (%) | h (calculated) | H (actual) | Error (%) |
| Copernicus | 2.28 | 3.80 | 40.00 | 2.04 | 3.80 | 46.32 | 2.35 | 3.80 | 38.16 |
| Reinhold | 3.80 | 3.00 | 26.67 | 4.86 | 3.00 | 62.00 | 4.96 | 3.00 | 65.33 |
| Lansberg | 4.11 | 3.10 | 32.58 | 3.70 | 3.10 | 19.35 | 4.74 | 3.10 | 52.90 |
| Bulliadus | 5.26 | 3.30 | 59.39 | 4.56 | 3.30 | 38.18 | 5.83 | 3.30 | 76.67 |
| Gauricus | 2.89 | 2.70 | 7.04 | 2.38 | 2.70 | 11.85 | 2.46 | 2.70 | 8.88 |
| Porter | 2.87 | 2.50 | 14.8 | 4.29 | 2.50 | 71.60 | 4.55 | 2.50 | 82.00 |
| Clavious | 4.12 | 3.50 | 17.71 | 3.84 | 3.50 | 9.71 | 6.12 | 3.50 | 74.86 |
| Rutherfurd | 3.38 | 2.40 | 40.83 | 2.99 | 2.40 | 24.58 | 3.74 | 2.40 | 55.83 |
| Average Error (%) | 25.37 | | | 35.44 | | | 56.82 | | |

From the study of lunar crater depth on the 8th day of the waning phase, it was found that at angles of elevation of 35°, 40°, and 45°, the percentage errors in the calculated crater depth were 25.37%, 35.44%, and 56.82%, respectively.

## Conclusion

From the study of lunar crater depth using trigonometric principles during the 8th day of the waxing and waning phases, the results

show that the waning phase provides greater accuracy, with an average percentage error of 25.37%, compared to 29.53% in the waxing phase, a difference of 4.16%. The angle of elevation significantly affects calculation accuracy; as the angle increases, the percentage error also increases, rising from 25.37% to 35.44% and 56.82%, respectively. Errors may result from several factors, including shadow clarity, the position of craters near the terminator where shadow lengths change rapidly, and the observer's measurement accuracy. Additionally, higher angles of elevation produce shorter shadows, making measurements more difficult and increasing error. These findings are consistent with related studies, indicating that accuracy depends primarily on shadow clarity and observational conditions, with the angle of elevation being a more influential factor than the lunar phase.

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