EXHIBIT 1

Lunar phase

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The **lunar phase** or **phase of the Moon** is the shape of the directly sunlit portion of the Moon as viewed from Earth. The lunar phases gradually and cyclically change over the period of a synodic month (about 29.53 days), as the orbital positions of the Moon around Earth and of Earth around the Sun shift.

The Moon's rotation is tidally locked by Earth's gravity; therefore, most of the same lunar side always faces Earth. This near side is variously sunlit, depending on the position of the Moon in its orbit. Thus, the sunlit portion of this face can vary from 0% (at new moon) to 100% (at full moon). The lunar terminator is the boundary between the illuminated and darkened hemispheres.

Each of the four "intermediate" lunar phases (see below) is around 7.4 days, but this varies slightly due to the elliptical shape of the Moon's orbit. Aside from some craters near the lunar poles, such as Shoemaker, all parts of the Moon see around 14.77 days of daylight, followed by 14.77 days of "night". (The side of the Moon facing away from Earth is sometimes called the "dark side of the Moon", although that is a misnomer.)

The lunar phases and librations in 2019 as viewed from the Southern Hemisphere at hourly intervals, with music, titles, and supplemental graphics


A full Moon sets behind San Gorgonio Mountain (in California) in a midsummer morning.

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Phases of the Moon [edit]

"Waxing gibbous" redirects here. For the album, see Waxing Gibbous.

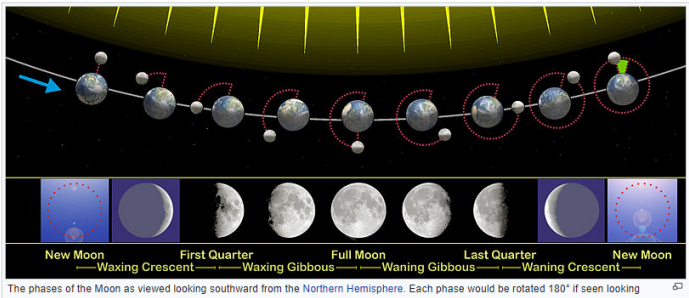
In western culture, the *four principal phases* of the Moon are new moon, first quarter, full moon, and third quarter (also known as last quarter). These are the instances when the Moon's ecliptic longitude and the Sun's ecliptic longitude differ by 0°, 90°, 180°, and 270°, respectively.[a] Each of these phases occur at slightly different times when viewed from different points on Earth. During the intervals between principal phases, the Moon's apparent shape is either crescent or gibbous. These shapes, and the periods when the Moon shows them, are called the *intermediate phases* and last one-quarter of a synodic month, or 7.38 days, on average. However, their durations vary slightly because the Moon's orbit is rather elliptical, so the satellite's orbital speed is not constant. The descriptor *waxing* is used for an intermediate phase when the Moon's apparent shape is thickening, from new to full moon, and *waning* when the shape is thinning.

The eight principal and intermediate phases are given the following names, in sequential order:

Principal and intermediate phases of the Moon

Moon Phase	Northern Hemisphere	Southern Hemisphere	Visibility	Mid-phase standard time	Average moonrise time	Average moonset time	Northern Hemisphere	Southern Hemisphere	Photograph (view from Northern Hemisphere)
New Moon	Disc completely in Sun's shadow (lit by earthshine only)		Invisible (too close to Sun)	Noon	6 am	6 pm			Not visible
Waxing crescent	Right side, 0.1%–49.9% lit disc	Left side, 0.1–49.9% lit disc	Late morning to post-dusk	3 pm	9 am	9 pm			
First Quarter	Right side, 50% lit disc	Left side, 50% lit disc	Afternoon and early evening	6 pm	Noon	Midnight			
Waxing gibbous	Right side, 50.1%–99.9% lit disc	Left side, 50.1%–99.9% lit disc	Late afternoon and most of night	9 pm	3 pm	3 am			
Full Moon	100% illuminated disc		Sunset to sunrise (all night)	Midnight	6 pm	6 am			
Waning gibbous	Left side, 99.9%–50.1% lit disc	Right side, 99.9%–50.1% lit disc	Most of night and early morning	3 am	9 pm	9 am			

Waning gibbous	Left side, 99.9%–50.1% lit disc	Right side, 99.9%–50.1% lit disc	Most of night and early morning	3 am	9 pm	9 am			
Last Quarter	Left side, 50% lit disc	Right side, 50% lit disc	Late night and morning	6 am	Midnight	Noon			
Waning crescent	Left side, 49.9%–0.1% lit disc	Right side, 49.9%–0.1% lit disc	Pre-dawn to early afternoon	9 am	3 am	3 pm			



The phases of the Moon as viewed looking southward from the Northern Hemisphere. Each phase would be rotated 180° if seen looking northward from the Southern Hemisphere. The upper part of the diagram is not to scale, as the Moon is much farther from Earth than shown here.

Non-Western cultures may use a different number of lunar phases; for example, traditional Hawaiian culture has a total of 30 phases (one per day).[1]

Waxing and waning [edit]

When the Sun and Moon are aligned on the same side of the Earth, the Moon is "new", and the side of the Moon facing Earth is not illuminated by the Sun. As the Moon *waxes* (the amount of illuminated surface as seen from Earth is increasing), the lunar phases progress through new moon, crescent moon, first-quarter moon, gibbous moon, and full moon. The Moon is then said to *wane* as it passes through the gibbous moon, third-quarter moon, crescent moon, and back to new moon. The terms *old moon* and *new moon* are not interchangeable. The "old moon" is a waning sliver (which eventually becomes undetectable to the naked eye) until the moment it aligns with the Sun and begins to wax, at which point it becomes new again.[2] *Half moon* is often used to mean the first- and third-quarter moons, while the term *quarter* refers to the extent of the Moon's cycle around the Earth, not its shape.

When an illuminated hemisphere is viewed from a certain angle, the portion of the illuminated area that is visible will have a two-dimensional shape as defined by the intersection of an ellipse and circle (in which the ellipse's major axis coincides with the circle's diameter). If the half-ellipse is convex with respect to the half-circle, then the shape will be gibbous (bulging outwards),[3] whereas if the half-ellipse is concave with respect to the half-circle, then the shape will be a crescent. When a crescent moon occurs, the phenomenon of earthshine may be apparent, where the night side of the Moon dimly reflects indirect sunlight reflected from Earth.[4]

A crescent Moon above Earth's horizon is featured in this 2010 photograph by an Expedition 24 crew member.

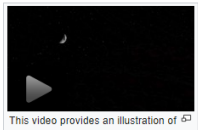
Orientation by latitude [edit]

In the Northern Hemisphere, if the left (east) side of the Moon is dark, then the bright part is thickening, and the Moon is described as waxing (shifting toward full moon). If the right (west) side of the Moon is dark, then the bright part is thinning, and the Moon is described as waning (past full and shifting toward new moon). Assuming that the viewer is in the Northern Hemisphere, the right side of the Moon is the part that is always waxing. (That is, if the right side is dark, the Moon is becoming darker; if the right side is lit, the Moon is getting brighter.)

In the Southern Hemisphere, the Moon is observed from a perspective inverted, or rotated 180°, to that of the Northern and to all of the images in this article, so that the opposite sides appear to wax or wane.

Closer to the Equator, the lunar terminator will appear horizontal during the morning and evening. Since the above descriptions of the lunar phases only apply at middle or high latitudes, observers moving towards the tropics from northern or southern latitudes will see the Moon rotated anti-clockwise or clockwise with respect to the images in this article.

The lunar crescent can open upward or downward, with the "horns" of the crescent pointing up or down, respectively. When the Sun appears above the Moon in the sky, the crescent opens downward; when the Moon is above the Sun, the crescent opens upward. The crescent Moon is most clearly and brightly visible when the Sun is below the horizon, which implies that the Moon must be above the Sun, and the crescent must open upward. This is therefore the orientation in which the crescent Moon is most often seen from the tropics. The waxing and waning crescents look very similar. The waxing crescent appears in the western sky in the evening, and the waning crescent in the eastern sky in the morning.



This video provides an illustration of how the Moon passes through its phases – a product of its orbit, which allows different parts of its surface to be illuminated by the Sun over the course of a month. The camera is locked to the Moon as Earth rapidly rotates in the foreground.

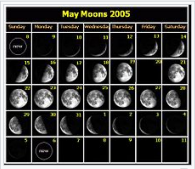
Earthshine [edit]

Main article: Earthlight (astronomy)

When the Moon as seen from Earth is a thin crescent, Earth as viewed from the Moon is almost fully lit by the Sun. Often, the dark side of the Moon is dimly illuminated by indirect sunlight reflected from Earth, but is bright enough to be easily visible from Earth. This phenomenon is called earthshine and sometimes picturesquely described as "the old moon in the new moon's arms" or "the new moon in the old moon's arms".

Calendar [edit]

Main article: Lunar calendar



May–June 2005 calendar of lunar phases

The Gregorian calendar month, which is $^{1}/_{12}$ of a tropical year, is about 30.44 days, while the cycle of lunar phases (the Moon's synodic period) repeats every 29.53 days on average. Therefore, the timing of the lunar phases shifts by an average of almost one day for each successive month. (A lunar year lasts about 354 days.)

Photographing the Moon's phase every day for a month (starting in the evening after sunset, and repeating roughly 24 hours and 50 minutes later, and ending in the morning before sunrise) and arranging the series of photos on a calendar would create a composite image like the example calendar (May 8 – June 6, 2005) shown on the left. May 20 is blank because a picture would be taken before midnight on May 19 and the next after midnight on May 21.

Similarly, on a calendar listing moonrise or moonset times, some days will appear to be skipped. When moonrise precedes midnight one night, the next moonrise will follow midnight on the next night (so too with moonset). The "skipped day" is just a feature of the Moon's eastward movement in relation to the Sun, which at most latitudes, causes the Moon to rise later each day. The Moon follows a predictable orbit every month.

An overexposed photograph of a crescent Moon reveals earthshine and stars.

Calculating phase [edit]

Each of the four intermediate phases lasts approximately seven days (7.38 days on average), but varies slightly due to lunar apogee and perigee.

The number of days counted from the time of the new moon is the Moon's "age". Each complete cycle of phases is called a "lunation".[5]

The approximate age of the Moon, and hence the approximate phase, can be calculated for any date by calculating the number of days since a known new moon (such as January 1, 1900 or August 11, 1999) and reducing this modulo 29.530588853 (the length of a synodic month). The difference between two dates can be calculated by subtracting the Julian day number of one from that of the other, or there are simpler formulae giving (for instance) the number of days since December 31, 1899. However, this calculation assumes a perfectly circular orbit and makes no allowance for the time of day at which the new moon occurred and therefore may be incorrect by several hours. (It also becomes less accurate the larger the difference between the required date and the reference date). It is accurate enough to use in a novelty clock application showing lunar phase, but specialist usage taking account of lunar apogee and perigee requires a more elaborate calculation.

A crescent Moon over Kingman, Arizona

Effect of parallax [edit]

The Earth subtends an angle of about two degrees, when seen from the Moon. This means that an observer on Earth who sees the Moon when it is close to the eastern horizon sees it from an angle that is about 2 degrees different from the line of sight of an observer who sees the Moon on the western horizon. The Moon moves about 12 degrees around its orbit per day, so, if these observers were stationary, they would see the phases of the Moon at times that differ by about one-sixth of a day, or 4 hours. But in reality the observers are on the surface of the rotating Earth, so someone who sees the Moon on the eastern horizon at one moment sees it on the western horizon about 12 hours later. This adds an oscillation to the apparent progression of the lunar phases. They appear to occur more slowly when the Moon is high in the sky than when it is below the horizon. The Moon appears to move jerkily, and the phases do the same. The amplitude of this oscillation is never more than about four hours, which is a small fraction of a month. It does not have any obvious effect on the appearance of the Moon. However, it does affect accurate calculations of the times of lunar phases.

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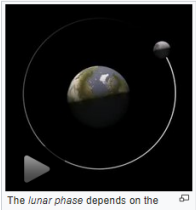
Misconceptions [edit]

It might be expected that once every month, when the Moon passes between Earth and the Sun during a new moon, its shadow would fall on Earth causing a solar eclipse, but this does not happen every month. Nor is it true that during every full moon, the Earth's shadow falls on the Moon, causing a lunar eclipse. Solar and lunar eclipses are not observed *every* month because the plane of the Moon's orbit around the Earth is tilted by about 5° with respect to the plane of Earth's orbit around the Sun (the plane of the ecliptic). Thus, when new and full moons occur, the Moon usually lies to the north or south of a direct line through the Earth and Sun. Although an eclipse can only occur when the Moon is either new (solar) or full (lunar), it must also be positioned very near the intersection of Earth's orbital plane about the Sun and the Moon's orbital plane about the Earth (that is, at one of its nodes). This happens about twice per year, and so there are between four and seven eclipses in a calendar year. Most of these eclipses are partial; total eclipses of the Moon or Sun are less frequent.



The *lunar phase* depends on the Moon's position in orbit around the Earth and the Earth's position in orbit around the sun. This animation (*not to scale*) looks down on Earth from the north pole of the ecliptic.

See also [edit]

- Blue moon
- Lunar effect
- Lunation
- Observing the Moon
- Planetary phase
- Planetshine
- Tides
- Week

Solar System portal

Footnotes [edit]

a. ^ Strictly, the quarter phases happen when the observer–Moon–Sun angle is 90°, also known as quadrature. This is not exactly the same as having the Sun–observer–Moon angle a right-angle, but the difference is very slight.

References [edit]

1. ^ "Hawaiian Moon Names". *Imiloa, Hilo Attractions.*
2. ^ "Free Astronomy Lesson 7 - The Phases of the Moon". *Synapses.co.uk.* Retrieved 2015-12-28.
3. ^ Origin: 1350–1400; Middle English < Latin *gibbōsus* humped, equivalent to *gibb* "(a) hump" + *-ōsus* "-ous"; "Gibbous". *Dictionary.com.*
4. ^ CNN, Leah Asmelash and David Allan. "A black moon is coming on July 31. Here's what that means". *CNN.*
5. ^ "Phases of the Moon and Percent of the Moon Illuminated". *aa.usno.navy.mil.* Retrieved 2018-02-12.

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General [edit]

- Six Millennium Catalog of Phases of the Moon [1]
- U.S. Naval Service on Moon Phase / What the Moon Looks Like Today (United States Naval Observatory)
- Full Moon Names
- Current Moon Phase
- The Length of the Lunar Cycle (numerical integration analysis)

Educational aids [edit]

- Open Source Physics Lunar Phase Model
- Lunar phase simulator (animation)
- Starchild: Moonlight Madness Lunar Phases Game
- Names and Images of the 8 moon phases
- Astrophysics Science Project Integrating Research & Education: Lunar Phases Quiz
- Lunar Phase Image Sets In High-Resolution (1200x1200 pixels) at 1-Degree Intervals - Views of the Moon From 4 Sides at Any Relative Phase
- Front/Back/East/West Lunar Phase Explorers
- Mnemonic devices for the Lunar phases
- Moon activity idea from Jet Propulsion Laboratory

V · T · E	The Moon [hide]
Physical properties	Internal structure · Topography · Atmosphere · Gravity field (Hill sphere) · Magnetic field · Sodium tail · Moonlight (Earthshine)
Orbit	Lunar distance · Orbital elements (Distance (Perigee and apogee) · Libration · Nodes (Nodal period) · Precession) · Syzygy (New moon · Full moon · Eclipses (Lunar eclipse (Total penumbral lunar eclipse · Tetrad) · Solar eclipse · Solar eclipses on the Moon · Eclipse cycle) · Supermoon) · Tide (Tidal force · Tidal locking · Tidal acceleration · Tidal range) · Lunar station
Surface and features	Selenography · Terminator · Hemispheres (Near side · Far side) · Poles (North pole · South pole (Face)) · Maria (List) · Mountains (Peak of eternal light) · Valleys · Volcanic features (Domes · Calderas · Lava tubes) · Craters (List · Ray systems · Crater of eternal darkness · South Pole–Aitken basin) · Soil (Swirls) · Rilles · Wrinkle ridges · Rocks (Lunar basalt 70017) · Water · Space weathering (Micrometeorite · Sputtering) · Quakes · Transient lunar phenomenon
Science	Observation · Libration · Lunar theory · Origin (Giant-impact hypothesis (Theia · Lunar magma ocean)) · Geology (Timescale (Late Heavy Bombardment) · Lunar meteorites · KREEP) · Experiments (Lunar laser ranging · ALSEP) · Lunar sample displays (Apollo 11 · Apollo 17) · Lunar seismology
Exploration	Missions (Apollo program) · Probes · Landing · Colonization · Tourism · Lunar resources
Time-telling and navigation	Lunar calendar · Lunisolar calendar · Month (Lunar month (Nodal period)) · Fortnight · Sennight · Lunar mansion · Lunar distance
Phases and names	New · Full (Names) · Crescent · Super and micro · Blood · Blue · Black · Dark · Wet · Tetrad
Related	Lunar effect · Moon illusion · Pareidolia (Man in the Moon · Moon rabbit) · Craters named after people · Artificial objects on the Moon · Memorials on the Moon · Moon in fiction · Moon landing conspiracy theories · Moon in mythology (Hjúki and Bil) · "Moon is made of green cheese" · Natural satellite · Double planet · Lilith (hypothetical second moon)
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