Physical Overview of the New Moon Lunar Phase

Ali Kyrala

The definition of the lunar phase known as "new moon" requires that the difference in celestial longitude between the sun and moon be zero. This however does not mean that the lines joining the lunar and solar centers with the earth center coincide in direction. One must recall that while the earth is moving in its (approximately) elliptical orbit about the sun in the ecliptic plane, the moon is traversing an (approximately) elliptical orbit about the earth in its own plane which is inclined about 5 degrees to the ecliptic plane.

The intersection of the lunar orbital plane with the ecliptic plane is called a lunar nodal line and this revolves through 360 degrees during 6,798 days. The lunar elliptical orbit also revolves about the earth within the lunar orbital plane with a perigee period of 3,232 days. During a solar eclipse, the moon is located on its nodal line which also ideally passes through the earth center and solar center. This alignment was the basis of the ancient Saros period of 6,585.33 days between eclipses calculated by the Chaldean astronomers of ancient Babylon.

The new moon phase occurs every month, during which the moon is not generally located on the nodal line or the ecliptic plane, although at the instant defining the simultaneous new moon and solar eclipse an initial assumption will be made that the axes of both earth and moon are orthogonal to the ecliptic taken as coincident with the lunar orbital plane. Although this is not quite correct it will serve to arrive at estimates which will later be modified to partially compensate for the actual axial misalignments. Starting then at the instant of solar eclipse, the motion of the moon in the orbital plane is followed while the earth is rotating 27.3 times as fast as the moon's angular velocity in its orbit.

A portion of the moon illuminated by the sun will first become visible at night when the projection on the ecliptic plane of the common tangent line (in the lunar orbital plane) separating earth and moon becomes parallel to the earth-sun line (see Figure 1). This requires about 1.2 degrees of lunar orbit or 2.18 hours. At this time the illuminated section of the moon will first become visible from the night side the earth. Since the moon only travels an average of 13.187 degrees per day and the earth is rotating 27.3 times as fast as the moon is orbiting, the slender crescent will not be visible for more than 25 minutes (6.09x24/360) after sunset before the earth rotates an observer at this location out of view. Even this would only occur under the idealized assumptions (including no refraction) made. Thus it seems that the observational determination of the new moon is of dubious reliability.

The average angular progress of the moon in its orbit is 13.1868 degrees per day (360/27.3). Hence in a halfday after the instant of the new moon it would achieve a maximum elongation of 6.1 degrees, reckoning a half degree of solar motion. Here a day (24 hours) is considered to be centered on the instant of the new moon (see Figure 1). Symmetrical results hold for the 12 hours before and after this instant.

For any lunar elongation within 12 hours of $t = 0$ (the instant of the new moon) the illuminated crescent will only be visible from earth locations on the line determined by A, B and the 2 poles (see Figure 3). The angular relationships are shown in Figure 2 while Figures 3 and 4 are enlarged views. Returning to Figure 3, it is seen that earth locations on the great circle through A and the poles will be instantly rotated out of view of the lunar crescent while locations on the great circle through B and the poles will retain the crescent in view while B is rotated into A. This will require a time equal to 25 minutes. The maximum angular width of the crescent is then given by δ. The intensity of light reflected from it should not exceed a fourteenth of the solar intensity.

The simplest way of accounting for the misalignment of the earth's axis is to regard the misalignment as having the effect of decreasing the effective rotation velocity of the earth by dividing by the cosine of the inclination. Thus cos 25,5 = 0.91704411 so the duration of observation would increase by 9%.

Using maximum elongation (within 1/2 day of $t = 0$) of 6.09 degrees for the line through A, one obtains 28 minutes = 25/cos 23.5°, where $\delta = 1.46 \times 10^{-5}$ degrees for the maximum duration of sighting and maximum angular width of crescent. Again, it seems that the observational determination of the new moon is of dubious reliability.

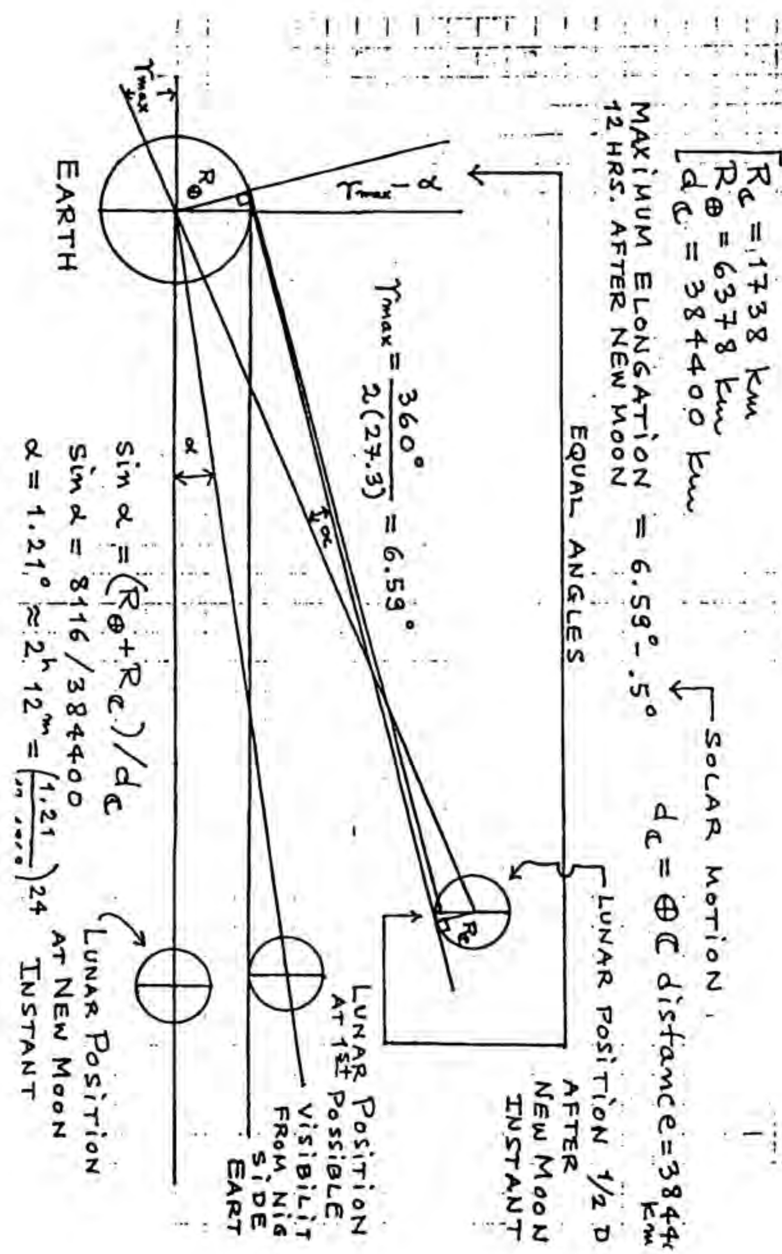
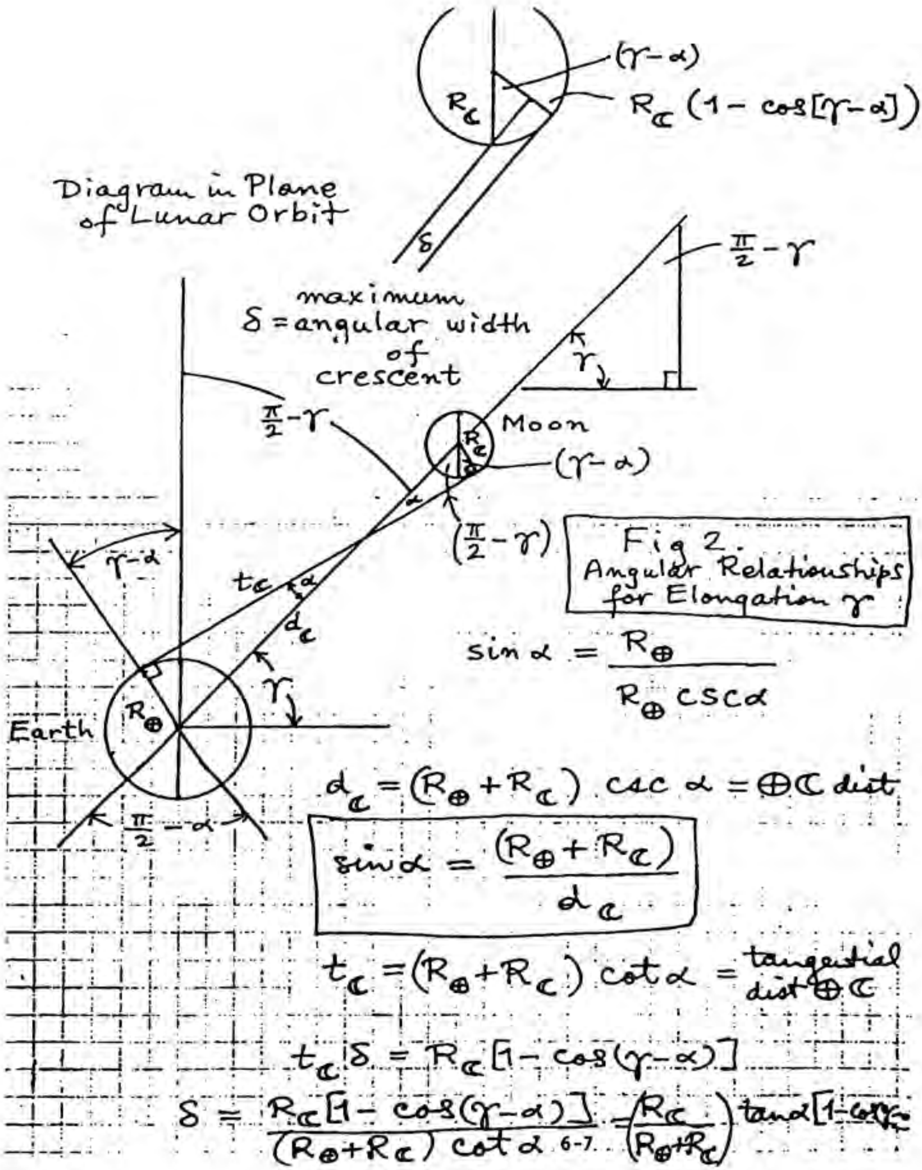

R☾ = 1738 km
R⊕ = 6378 km
d☾ = 384400 km
MAXIMUM ELONGATION = 6.59° - .5°
12 HRS. AFTER NEW MOON
EQUAL ANGLES
SOLAR MOTION
γmax = 360° / 2(27.3) = 6.59°
γmax - α
sin α = (R⊕ + R☾)/d☾
sin α = 8116/384400
α = 1.21° ≈ 2h 12m
LUNAR POSITION 1/2 D AFTER NEW MOON INSTANT
LUNAR POSITION AT NEW MOON INSTANT
EARTH

Figure 1.

Figure 2.



(γ − α)
R☾ (1 − cos[γ − α])
R☾
Diagram in Plane of Lunar Orbit
δ
π/2 − γ
γ
maximum δ = angular width of crescent
π/2 − γ
Moon
R☾
(γ − α)
α
(π/2 − γ)
Fig 2. Angular Relationships for Elongation γ
γ − α
t☾
α
d☾
γ
sin α = R⊕ / R⊕ csc α
Earth
R⊕
π/2 − α
d☾ = (R⊕ + R☾) csc α = ⊕☾ dist
sin α = (R⊕ + R☾) / d☾
t☾ = (R⊕ + R☾) cot α = tangential dist ⊕☾
t☾ δ = R☾[1 − cos(γ − α)]
δ = R☾[1 − cos(γ − α)] / (R⊕ + R☾) cot α = (R☾ / (R⊕+R☾)) tan α [1 − cos(γ − α)]
6-7

Figure 3.

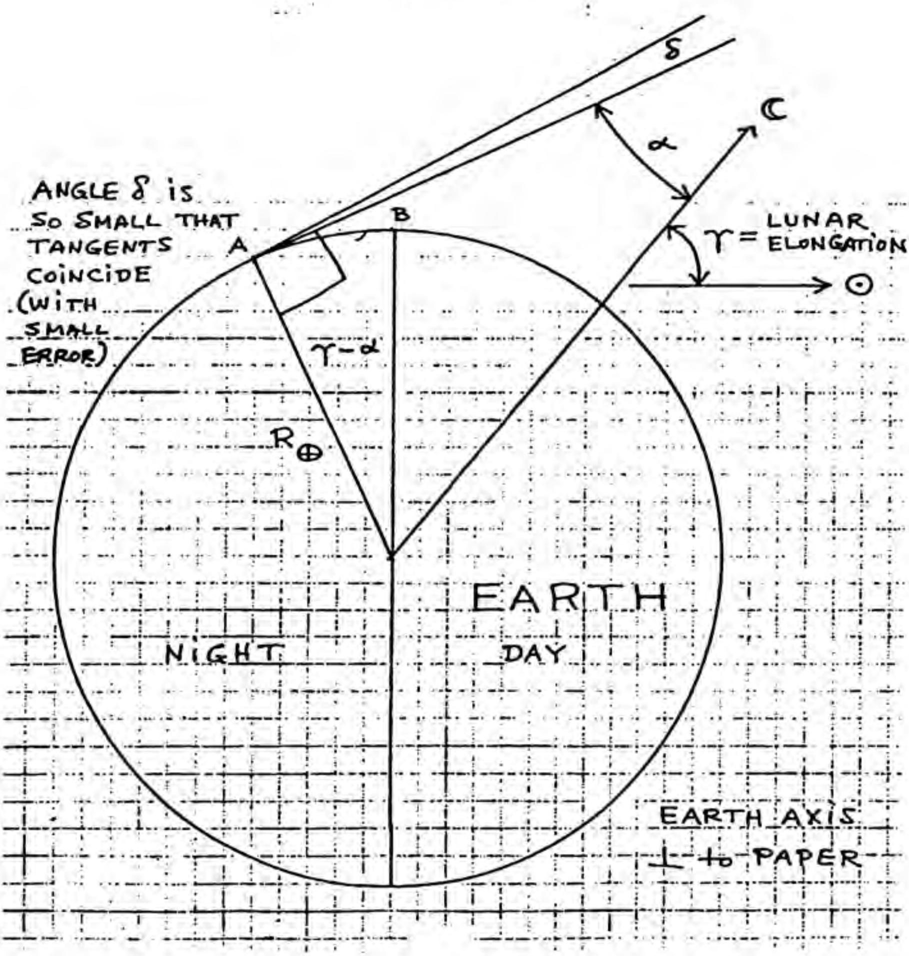
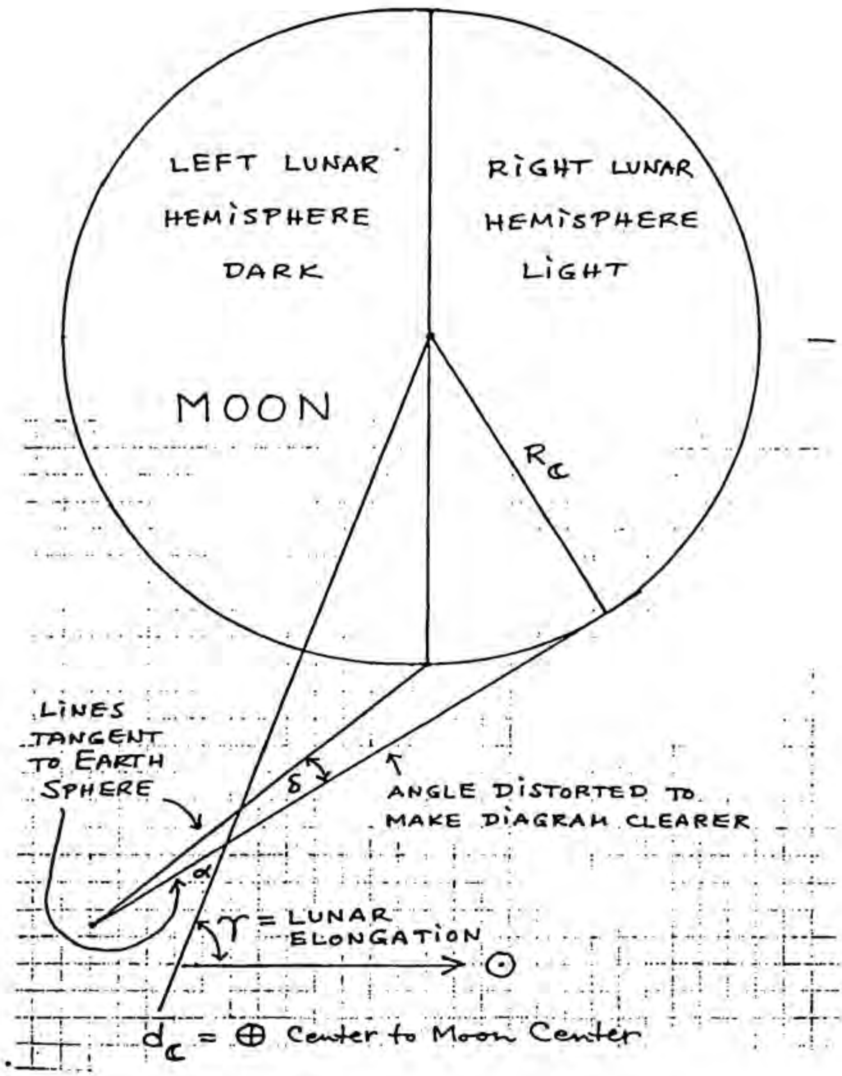

δ
α
☾
ANGLE δ IS SO SMALL THAT TANGENTS COINCIDE (WITH SMALL ERROR)
B
A
γ = LUNAR ELONGATION
☉
γ−α
R⊕
EARTH
NIGHT
DAY
EARTH AXIS ⊥ to PAPER

Figure 4.


LEFT LUNAR
HEMISPHERE
DARK
RIGHT LUNAR
HEMISPHERE
LIGHT
MOON
LINES
TANGENT
TO EARTH
SPHERE
ANGLE DISTORTED TO
MAKE DIAGRAM CLEARER
= LUNAR
ELONGATION
Center to Moon Center