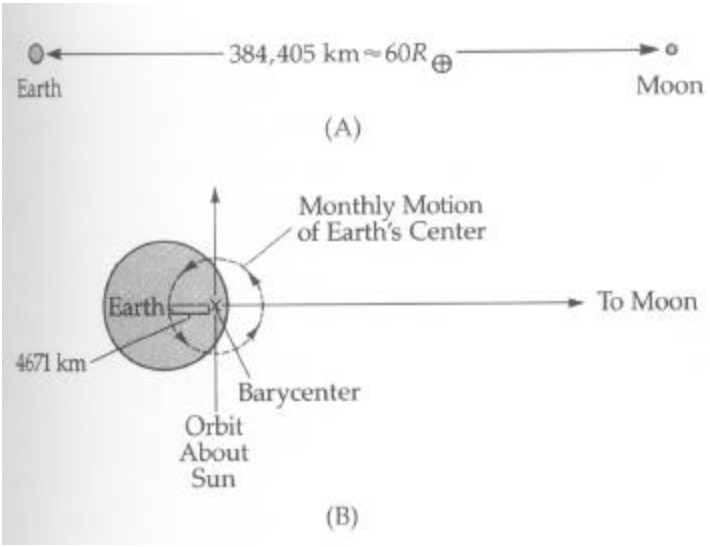
Dynamics of the Earth-Moon System

Determination of parameters



Masses:

Earth - from satellite orbits using Kepler's 3rd Law. Need *G*.

Moon - from Earth mass and location of barycenter (center of mass).

Earth-Moon distance: radar pulses ($\delta \sim$ few m), laser from mirrors ($\delta \sim 1$ cm).

Radii: Earth - satellites, radar (but Eratosthenes ~ 250 BC).

Moon - from E-M distance and apparent size.

Motions

• Barycenter orbits Sun with sidereal period P_E= 365.2564 days.

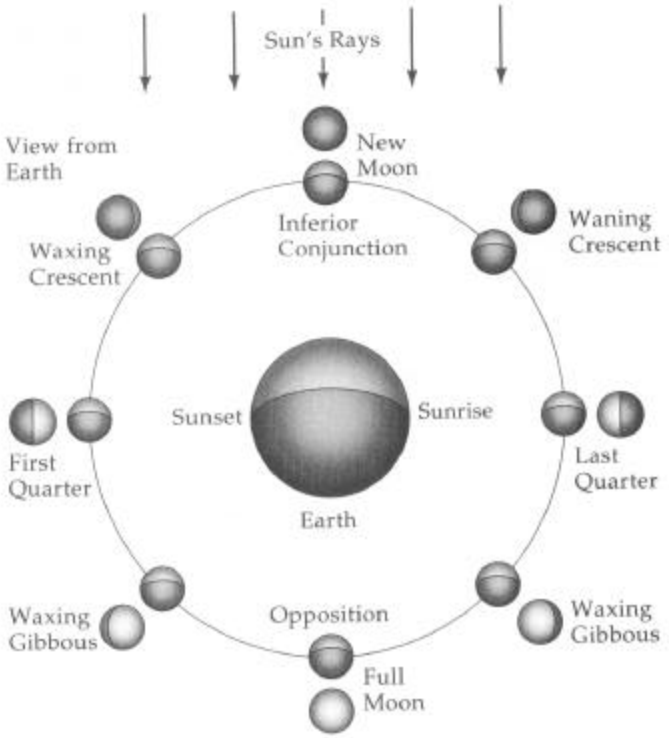
• Earth-Moon sidereal orbit period P_M= 27.322 days. Synodic period S_M= 29.531 days. In fact, 1/ S_M = 1/ P_M - 1/ P_E.

• Moon's rotation period = sidereal orbit period, due to tidal effect. Therefore, only see one face of the Moon from Earth.

• Tidal friction is also slowing down the Earth's rotation rate, by 0.002s/100 yr.

• Earth's precession due to tides has period 26,000 yr.

Phases



The Sun always illuminates one hemisphere of the Moon, but we see various fractions of the sunlit hemisphere depending on the Moon's elongation.

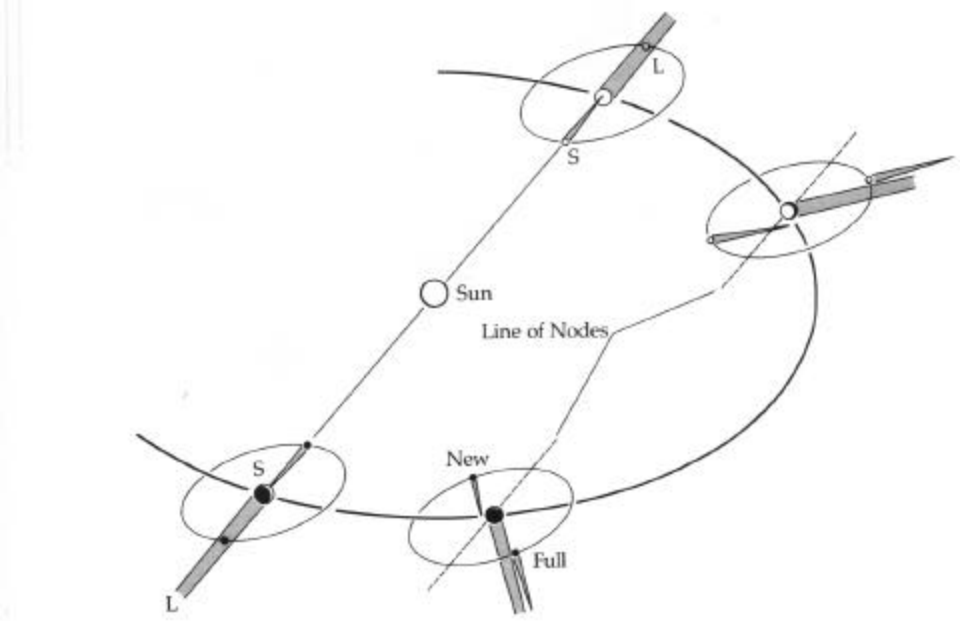
New (inferior conjunction) - waxing crescent - first quarter (quadrature) - waxing gibbous - full (opposition) - waning gibbous - third quarter (quadrature) - waning crescent.

Eclipses

When the shadow of one body falls upon another.

The Sun's apparent angular size, 32', nearly the same as that of the Moon!

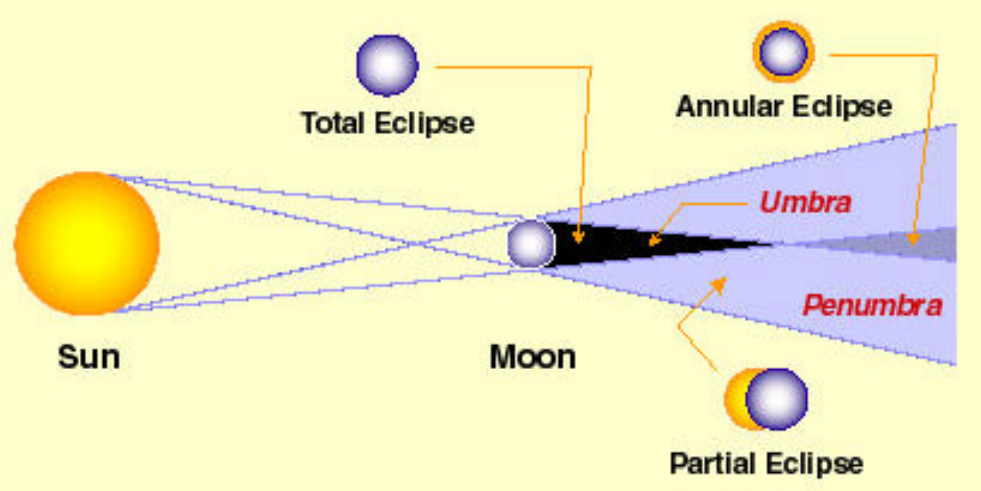
Moon's orbit plane inclined 5^0 from the ecliptic. Line of nodes = intersection of Moon's orbit plane with ecliptic. It lines up along Earth-Sun line only twice per year.



When this occurs, a new moon can lead to: partial solar eclipse, annular solar eclipse, or total solar eclipse.

Full moon leads to: partial, penumbral, or total lunar eclipse.

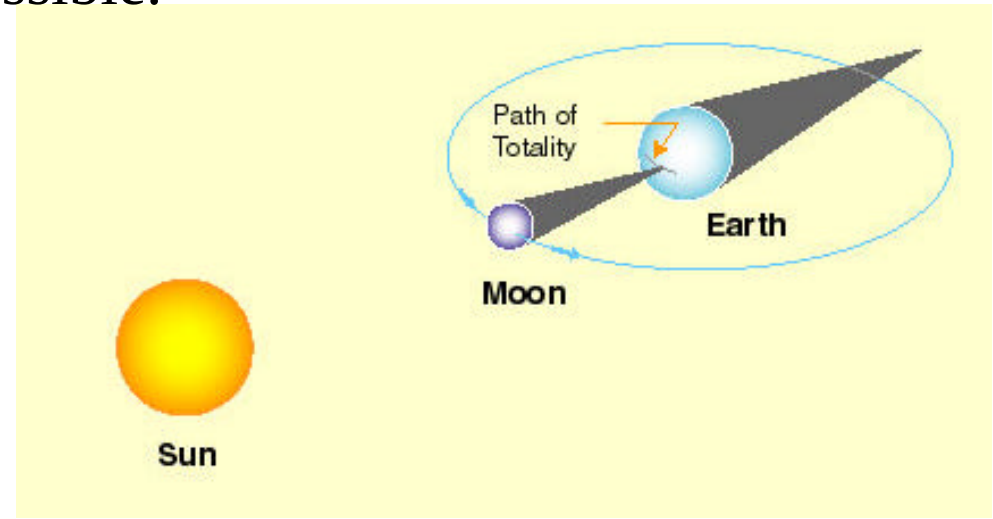
Solar Eclipse



Occurs when the Earth enters the Moon's shadow.

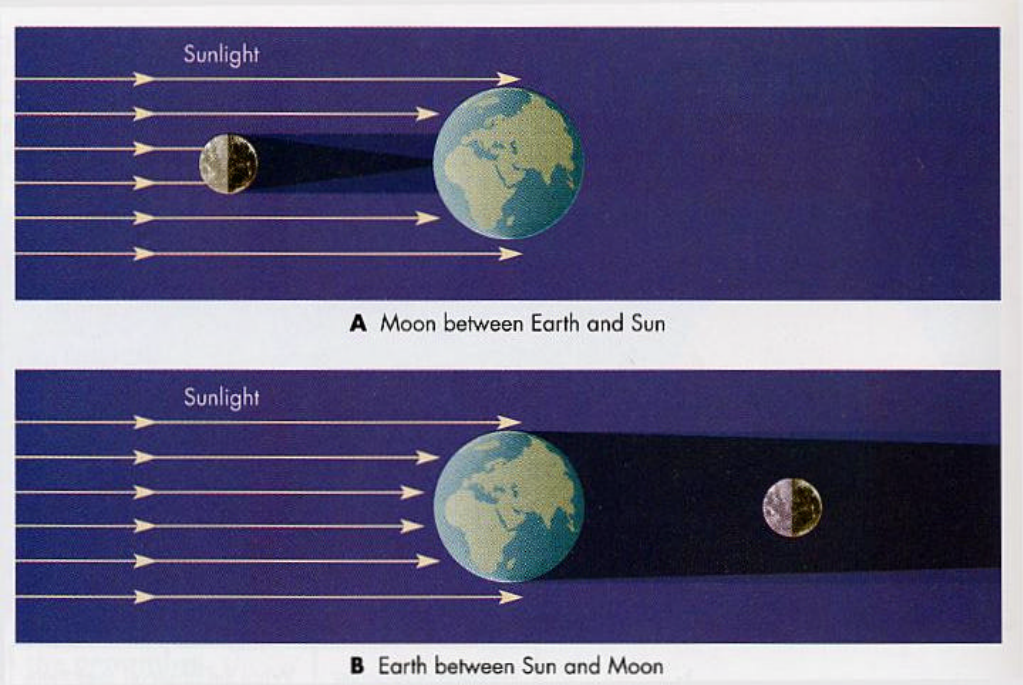
Moon's umbral shadow extends about 371,000 km. Average Earth-Moon distance is 378,000 km, but varying distance means that a total eclipse is sometimes possible.

Only a small region on Earth gets to view total eclipse.



Lunar Eclipse

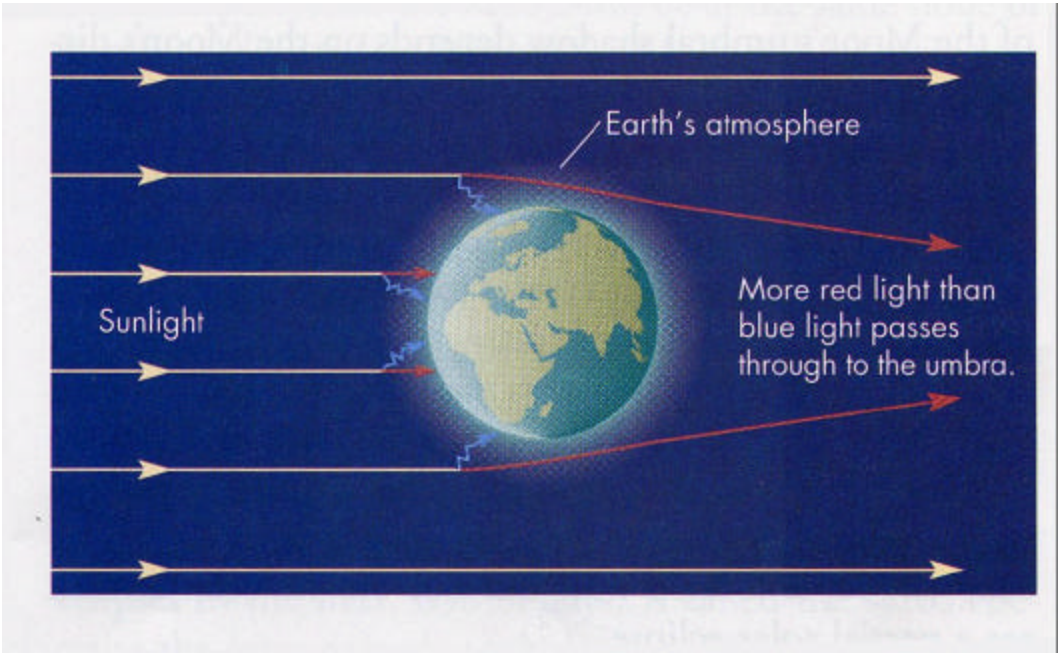
Seem much more common than solar eclipses. Why?



Earth's umbral shadow extends 1,380,000 km, much further than the Moon. The Moon can be entirely enveloped in the Earth's umbral shadow => total lunar eclipse. Hence, people all over the night side of Earth can see the eclipse.

Lunar Eclipse

The Moon often looks red or coppery during an eclipse. Why?



Sunlight refracted into the umbra. More red light then blue light passes through the atmosphere and into the umbra.

Eclipse cycles

The Line of Nodes points directly enough at the Sun for eclipses to occur during one month intervals which are 5.7 months apart. These times are known as eclipse seasons.

Upcoming eclipses:

Date	*Type*	*Where*
Nov. 20, 2002	Penumbral lunar	Atlantic Ocean
Dec. 4, 2002	Total solar	S. Africa, Australia
May 16, 2003	Total lunar	N. & S. America
May 31, 2003	Annular solar	Iceland
Nov. 9, 2003	Total lunar	W. Asia, Europe, Africa
Nov. 23, 2003	Total solar	Antarctica

Eclipse cycles

Suppose a solar eclipse occurs today at a given location. When will the Sun, Earth, and Moon be aligned again in exactly the same way?

Line of Nodes aligns same way with Sun every eclipse year = 346.6 days.

Moon returns to the same phase every synodic month = 29.5 days.

After 6585 1/3 days, both the Moon phase and Line of Nodes have gone through a full number of cycles.

Eclipse cycles

An eclipse repeats after 6585 1/3 days = 18 years, 11 1/3 days. This time is called the *saros*. Shadow on Earth is shifted extra 1/3 way around Earth.

An even closer repetition occurs every 3 saros periods or 54 years, 34 days.