Earth, Moon and Sun

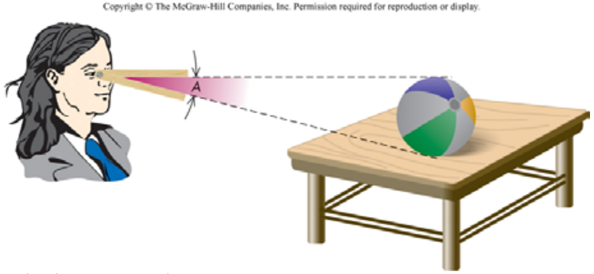
Ancient Greek Astronomy

- ~ 200 B.C. : explanation and understanding of astronomical facts
- Ancient Greek astronomers did know that the Earth is round
- Geometry was developed (300 B.C.)
- Sizes and relative distances of Earth, Moon and Sun
- First heliocentric model of the Solar System (not officially accepted)
- Eclipses

The Earth is round because:

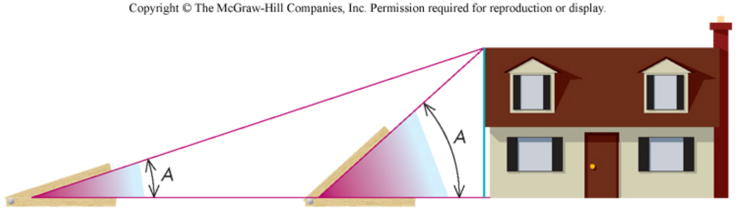
- If you stand on the seashore and watch a ship sailing away, it will *gradually* disappear from view
- The *round shadow* of the Earth on the moon during eclipses clearly showed the spherical shape of the Earth
- The *height of the Northern Star* changes, when we travel between the NP and Equator
- We see *different stars* traveling N-S
- *Falling objects* should move toward the center of the Earth and perpendicularly to the surface of the Earth

Angular size, angular distance

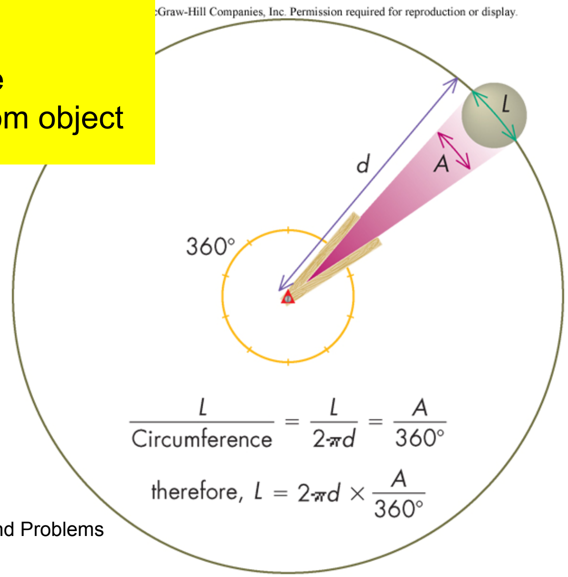


- A circle has 360 degrees
- 1 degree is 1/360 of a circle
- 1 arcmin, 1 arcsec
- 1 degree = 3600 arcsec

Angular size of object is inversely proportional to distance from object



L=Linear size
A=angular size
d= distance from object



Practice:
Unit 10: Example and Problems

L=Linear size
A=angular size
d= distance from object

Angular size in Astronomy – very small

Use arcseconds

L=(2x3.14)/(3600x360) x (d x A(arcsec))

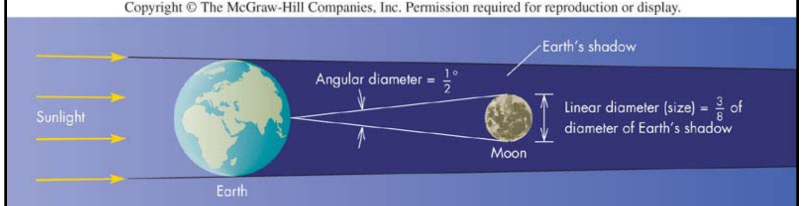
L = (1/206265) x d x A(arcsec)

small angle equation

Aristarchus found the linear size of the Moon

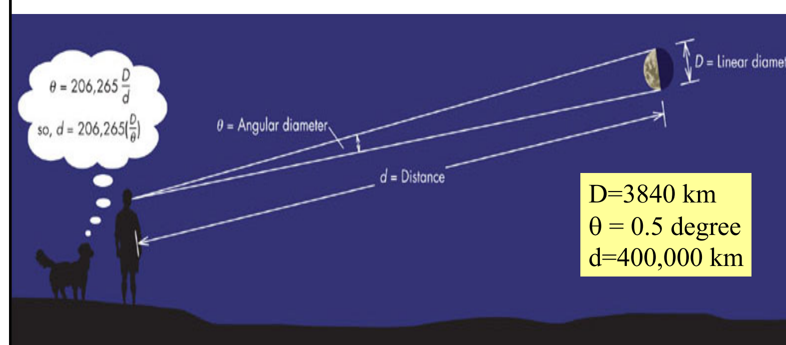
Moon's angular diameter – measured directly
Moon's linear diameter – calculated:

- **Use lunar eclipses to find the relative sizes of Earth and Moon**
- **Earth's shadow is a cone, but we can think of a cylinder**
- **Observe with how many lunar diameters the Moon moves while it is completely within the Earth shadow**
- **Diameter of Moon = 3/8 of the diameter of Earth**

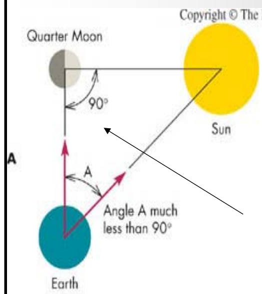


Aristarchus found the distance to the Moon

Moon's angular diameter – measured directly
Moon's linear diameter – from calculations
Distance to Moon – using the small angle equation

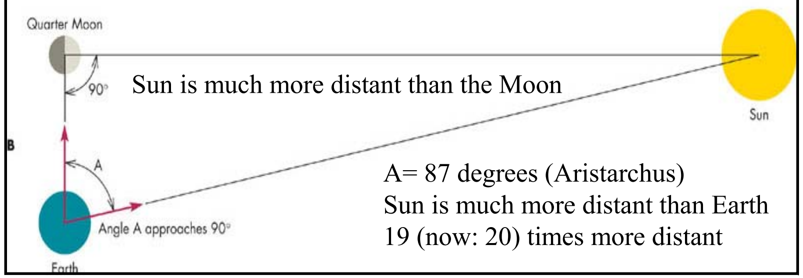


Aristarchus estimated the relative distance of the Sun and the Moon



Observing the angle A at a "Quarter Moon"

Comparable distances to Sun and Moon: angle A should be about 45 degrees

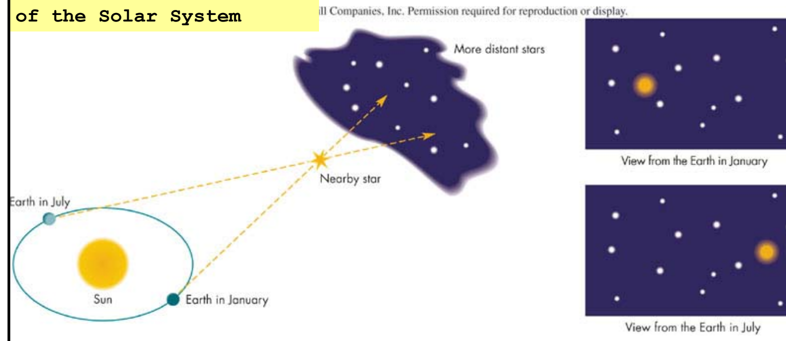


Sun is much more distant than the Moon

A= 87 degrees (Aristarchus)
Sun is much more distant than Earth
19 (now: 20) times more distant

Stellar parallax

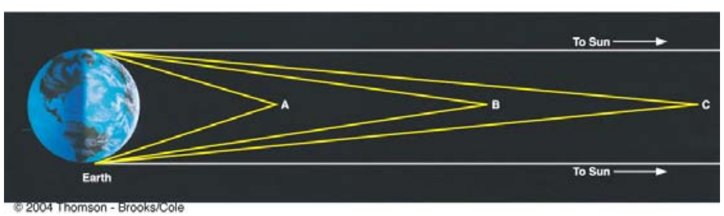
Aristarchus (250 B.C.)
The first one to propose the heliocentric model of the Solar System



- Annual apparent change in the position of a star caused by the motion of the Earth around the Sun.
- Detecting parallaxes means that Earth orbits around Sun.
- Ancient Greek astronomers could not detect stellar parallax.

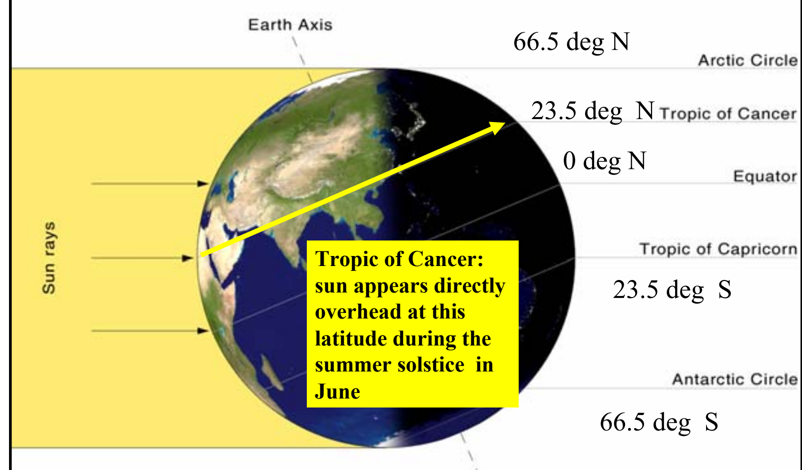
Measuring the size of the Earth

Eratosthenes 235 B.C.



Used the fact that the Sun is so distant from us that all the light rays that strike the Earth are parallel to each others.

The five major circles of latitude

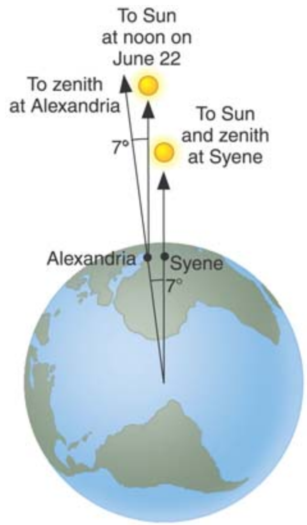


Tropic of Cancer: sun appears directly overhead at this latitude during the summer solstice in June

Measuring the size of the Earth

The experiment:

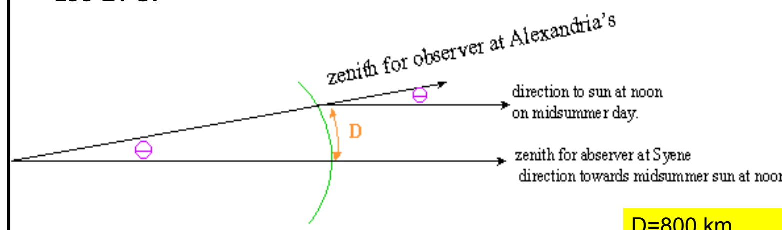
- At noon, during the summer solstice the Sun is directly at the city of Syene
- At the same time at the city of Alexandria, the light from the Sun makes an angle of 7.2 degrees with the vertical
- Distance Alexandria – Syene = 800 km



Measuring the size of the Earth

ERATOSTHENES

235 B. C.

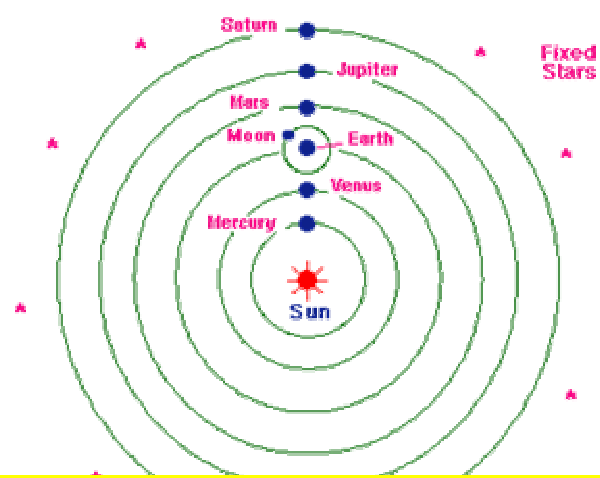


D=800 km
Θ= 7.2 deg
C = 40 000 km
R = 6400 km

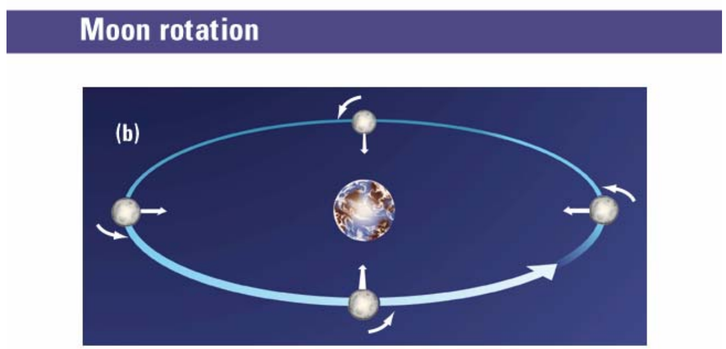
$$\frac{\Theta}{360^\circ} = \frac{D}{\text{Circumference of the Earth}}$$

Measuring the size of the Earth

How much would be the radius of the Earth, if Eratosthenes had measured at the city of Alexandria, that the light from the Sun made an angle of 16 degrees with the vertical?



Moon orbits the Earth
Earth orbits the Sun
Apparent motion of Sun and Moon in the sky



Looking down on the Earth and Moon from above the Earth's north pole, we see that its revolution is in the *same* counterclockwise direction as the Earth's rotation (and also the Earth's revolution around the Sun).

Ecliptic

To us it looks that Sun moves across the Celestial Sphere during the year.
Apparent path of Sun on the celestial sphere – Ecliptic.

The Motion of the Moon

Daily (E to W)

Shifts its position across the background stars (W to E) 12 times faster than the Sun

Takes 27.32 days to make a complete trip around the celestial sphere with respect to the stars – sidereal month (true orbital period)

Changes its position with respect to Sun: synodic (lunar) month – time to complete one cycle of phases – 29.53 days

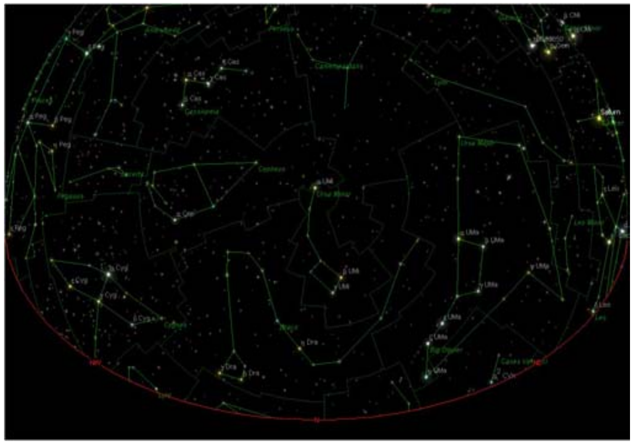
Relative Motion

Observer travels N-S.
All objects at rest along the road “travel” S-N.

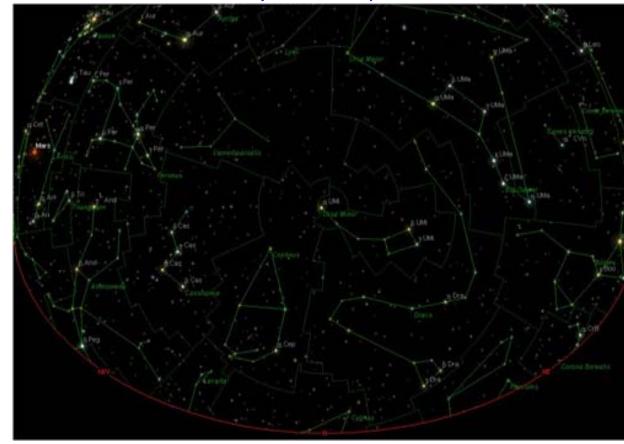
Earth spins W-E (counterclockwise if we look down at Earth from above the North Earth Pole).

The Night sky spins E-W (counterclockwise looking toward Polaris from the surface of Earth)

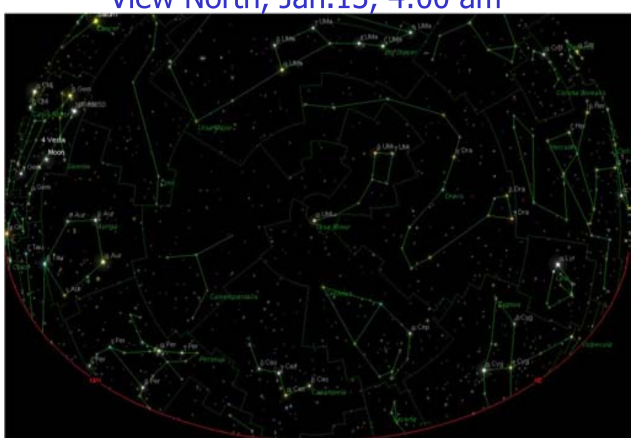
View North, Jan.12, 8 pm:



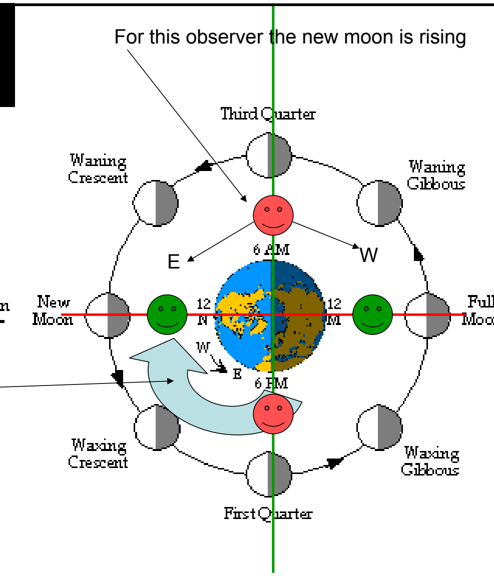
View North, Jan.13, 0:00 am:



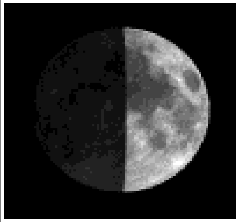
View North, Jan.13, 4:00 am

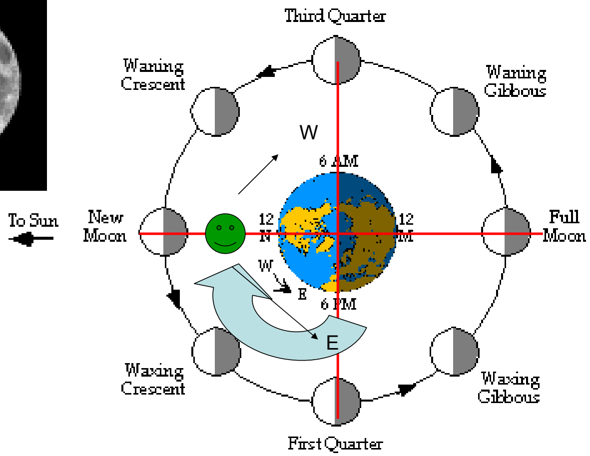


Looking North – sky rotates around Polaris

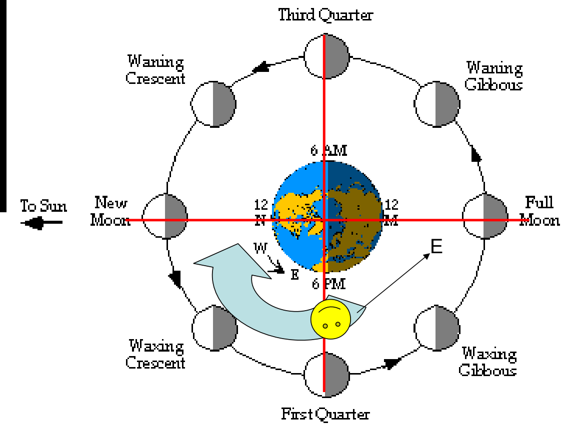


New Moon:
Rises and sets with Sun.

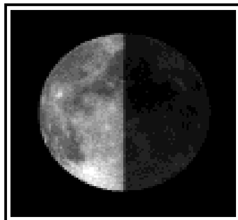


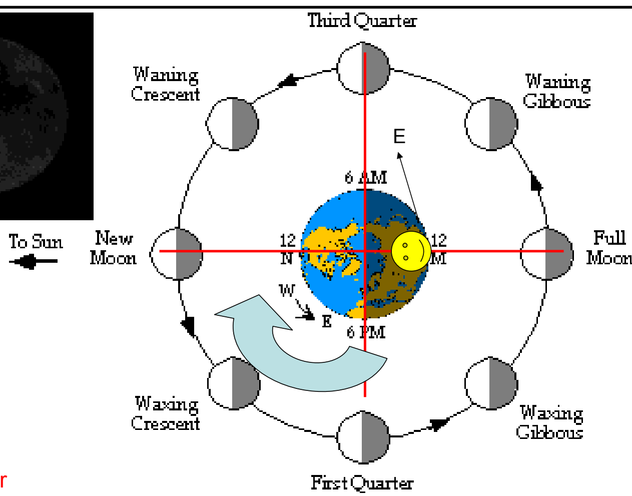


First Quarter:
Rises (when is it located at the eastern horizon?) – 12 noon
Sets – 12 midnight



Full Moon:
Rises (when is it located at the eastern horizon?) – 6 pm
Sets – 6 am



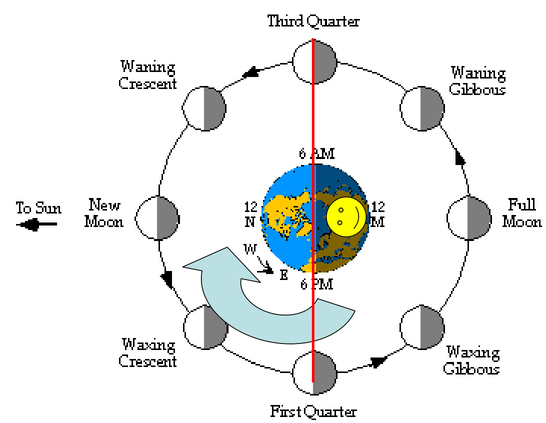


Third Quarter

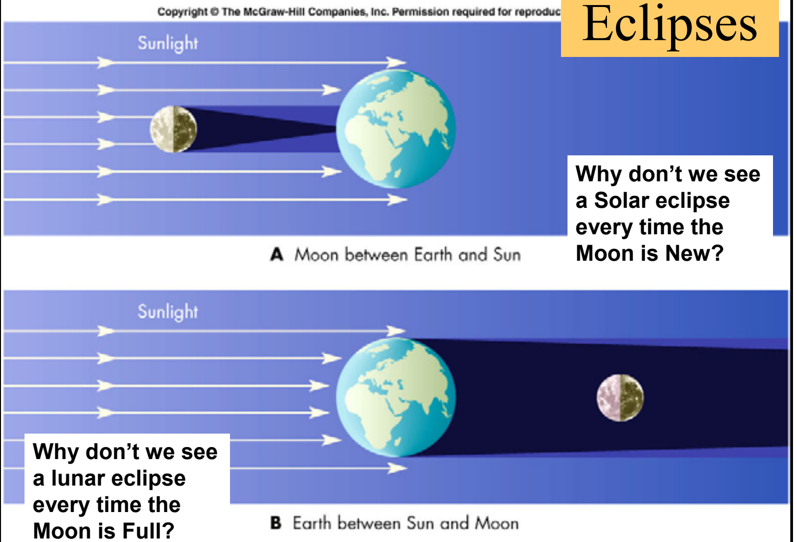
Rises (when is it located at the eastern horizon?) – 12 midnight
Sets – 12 noon

Review Question

If it's midnight and the Moon is rising, what phase is it?

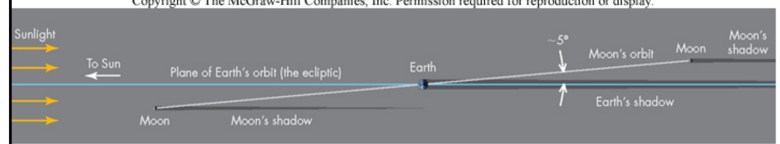


Eclipses

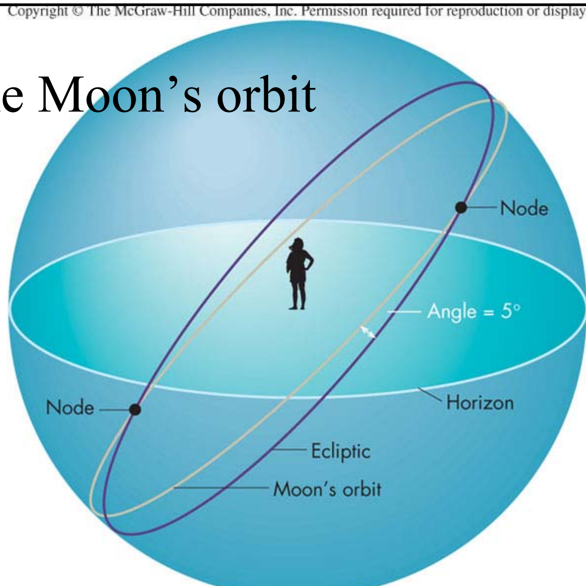


Why don't we see a Solar eclipse every time the Moon is New?

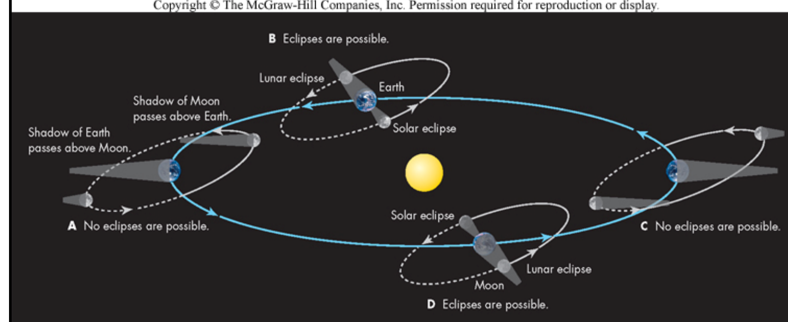
Why don't we see a lunar eclipse every time the Moon is Full?



The Moon's orbit

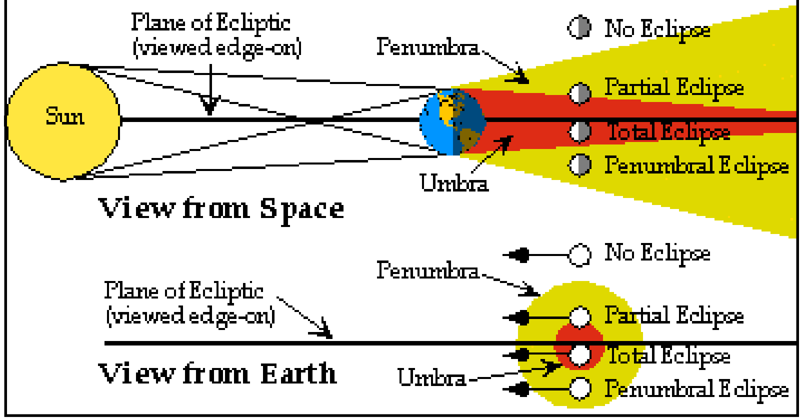


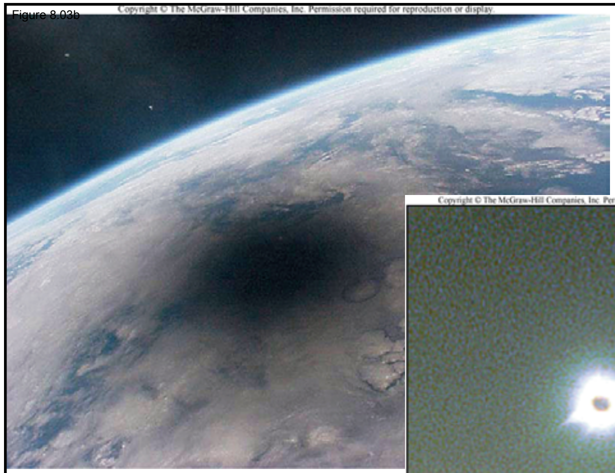
The Moon's orbit



When an eclipse is possible?
Precession of the Moon's orbital plane
Pattern of eclipses tend to be similar every 18 years
~ 18 year period - Saros

Lunar
Eclipses



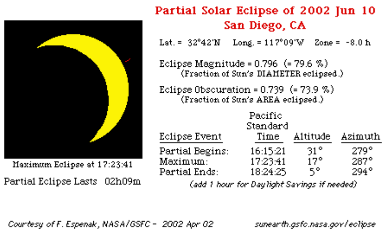


The Moon's shadow has a maximum diameter on the surface of the Earth of 270 Km.

Partial Solar Eclipse

If you are located in the Moon's **penumbra**, which is much larger than the umbra, the Sun is only partially blocked out.

This incomplete covering of the Sun is called a **partial solar eclipse**.

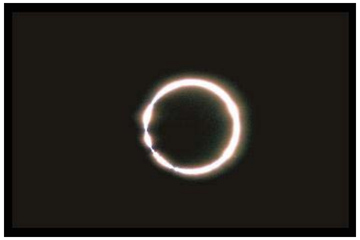


Annular Solar Eclipse

When the Moon is farthest from us, the tip of the umbra doesn't quite reach the Earth.

From our point of view here on the Earth, the Moon does not quite cover the Sun, so a ring of sunlight will surround it.

This type of partial eclipse is called an **annular eclipse**.



Annular Solar Eclipse 30 May 1984

http://solareclipsewebpages.users.btopenworld.com

The Frequency of Eclipses

Because of the finite size of the Earth, Moon, and their shadows, multiple eclipses can occur whenever the line of nodes points near the Sun.

Eclipses are actually very common!

During a one-year period, there can be between two and five eclipses of each kind (solar and lunar), with a total of between four and seven.

This includes partial and penumbral lunar eclipses, and partial and annular solar eclipses.

Lunar eclipses are much more likely to be observed, since anyone on the night side of the Earth can see them.

Solar eclipses, on the other hand, cover only a small fraction of the Earth, and often occur over unpopulated locations such as the polar regions or the oceans