History of Astronomy Notes

Aug 21-9:35 AM

Why did ancient cultures study astronomy?

Aug 21-7:40 AM

Remember how the location of the sunrise changes due to the tilt of the Earth?

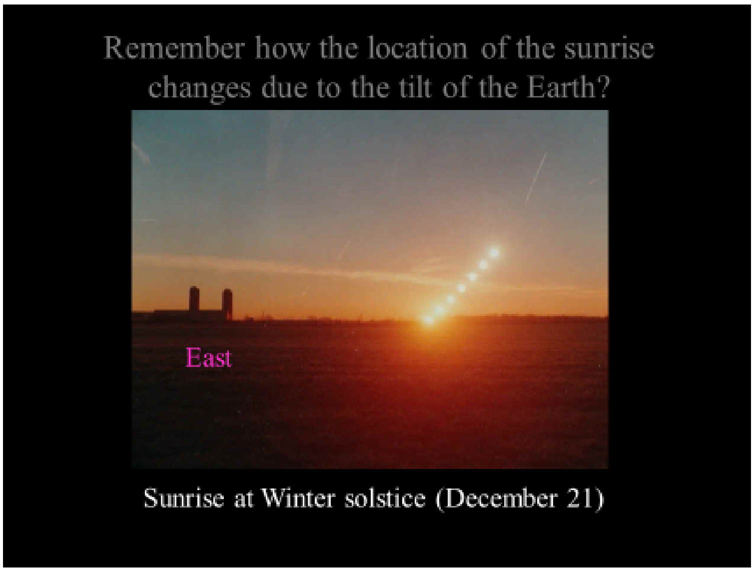
Sunrise at summer solstice (June 21)

Aug 21-7:41 AM

Remember how the location of the sunrise changes due to the tilt of the Earth?

Sunrise at Fall equinox (Sept 21)

Aug 21-7:41 AM



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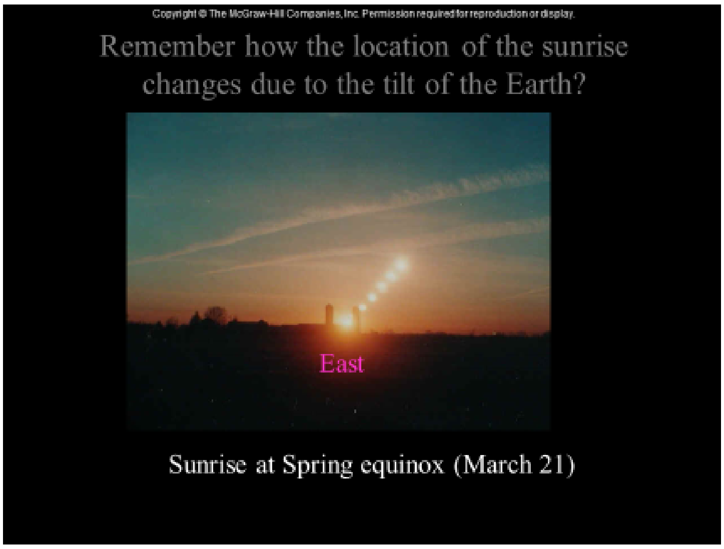

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Ancient cultures noticed this too...
Ancient cultures also noticed, calculated, and predicted the positions of other stars and planets.

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Why did ancient cultures study astronomy?

- ❑timekeeping
- ❑agriculture (planting crops or hunting and fishing cycles)
- ❑astrology/religion
- ❑and to keep accurate historical records.

- ❑Here are some historical contributions . . .

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Babylonians/Mesopotamians

- **Ziggurats**— observational structures & places of worship
- Identified zodiac constellations
- Studied cycles of planets, Sun, Moon
- Astrology and religion purposes

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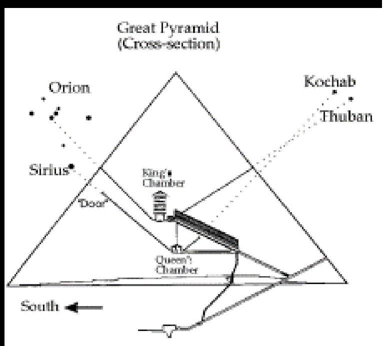
Egyptians

- Established calendar of 365 days
- Pyramid alignment with stars (religious)
- the star, Sirius, marked the annual flooding of the Nile and fertile season



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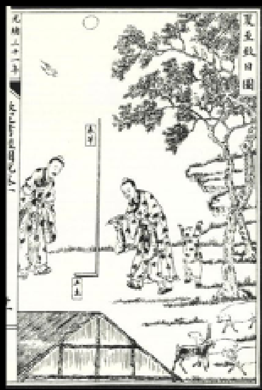
Chinese

- Kept accurate records for historical purposes
- Led to accurate timekeeping
- Recorded comets, eclipses, and supernova ("guest star") in 1054 B.C.



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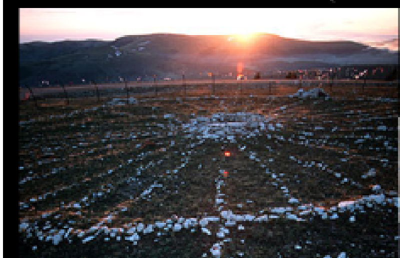
Native American (Bighorn medicine wheel) and Incan (Machu Picchu)



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Define Archeoastronomy- *the study of ancient astronomy*

Newgrange Location: *Ireland* Year *5000 years ago*

Description: *buried dead facing sunrise on the summer solstice*

Purpose: *connection with the dead in the spirit world*

Navajo Indians: *Description: doors of their homes facing toward the rising sun, connection with the spirit world*

Temple of Isis Location: *Egypt* Year: *2000 years ago*

Description: *clock made of stone, a way to tell time and calendar*

Aug 21-7:21 AM

Sun Dagger: Location: *New Mexico*

Description: *Opening within the rock that the summer solstice light shines through marking the rock*

Purpose: *calendar of time*

Mayan Tables:

Description: *Written record in books*

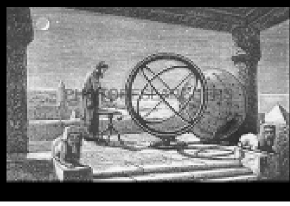
What was the fate of their documents? *Destroyed by fire*

Aug 21-7:22 AM

What did the Greeks do that other cultures had not done?

The Greeks actually came up with ***models*** of how things might work in the sky and in space.

Starts with careful measurements of the Sun (time of day and time of year) in sundials…this moves into armillary spheres and models.



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General Information of Historical Models

- Models tried to explain motion of planets, the sun, and the moon and why they move through the fixed stars.
- Models tried to account for **retrograde motion** of planets (this was the **biggest problem** in finding a model that worked accurately).
- Astronomy and mathematics advanced side-by-side because it gave cultures problems to solve and calculate
- **GEO**centric--Earth centered universe
- **HELIO**centric--Sun centered universe

Aug 21-7:44 AM

Ancient Greek Astronomers

- Through the use of models and observations, they were the first to use a careful and systematic manner to explain the workings of the heavens
- Limited to naked-eye observations, their idea of using logic and mathematics as tools for investigating nature is still with us today
- Their investigative methodology is in many ways as important as the discoveries themselves

Aug 21-7:33 AM

The Astronomy of the Greeks

Greek astronomy was influenced by the *Egypt* and *Babylonian*.

What influenced the previous cultures ideas of astronomy? *Religion and astrology*

How was the Greek's study of astronomy different than the other cultures? *Scientific attitude to try and understand the universe*

Thales of Miletus- Date *624-547 BC*

What was his influence on astronomy: *universe was rational and could be understood*

How were his ideas different from earlier philosophers? *Departure from mystic beliefs*

Aug 21-7:22 AM

Pythagoras- Date *570-500 BC*

What did he propose about nature? Underlining musical tendency basically harmonic motions, mathematical basis

What did Pythagoras say influences the celestial sphere? *Governed by geometrical and mathematical relations*

How did Pythagoras describe the Earth and other heavenly bodies in or solar system? *Earth was a sphere and other heavenly bodies, divine perfect spheres moving in perfect circles*

In trying to understand the universe, what did the Greeks do that the Babylonian astronomers never did? *Constructed models based on geometric forms*

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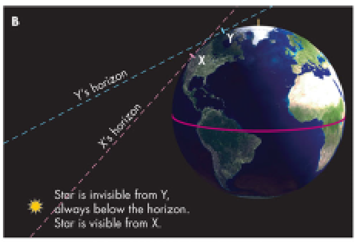
Early Ideas: Pythagoras

- Pythagoras taught as early as 500 B.C. that the Earth was round, based on the belief that the sphere is the perfect shape used by the gods



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Anaximander (c 611-546 BC) *contribution: wheels filled with fire, sun and moon are holes in the wheel where the flames can be seen*

Philolaus (5thc BC) *contribution: Earth moves around a fire not the sun. First theory of earth's motion*

Plato (428-347 BC) describe the principle of uniform circular motion- *heavens were made up of multiple rotating spheres*

Eudoxus (409-356 BC) describe his model of the universe- *said the universe was made of 27 nested spheres rotating at different rates on different axis*

Aug 21-7:25 AM

Aristotle (384-322 BC)

Believed the universe was divided into 2 parts: *Earth* and *Heavens*

Describe his geocentric universe model: *Earth centered with heavens surrounding 55 crystalline spheres*

How did he describe the movement of the sky to produce motions of the sun, planets, and moon? *Turning rates and different angles to carry the sun, moon, and stars across the sky.The moon is the boundary. The area below the moon is changeable and imperfect, the area above the moon sphere is perfect and unchanging*

Aug 21-7:26 AM

Early Ideas: Aristotle

- By 300 B.C., Aristotle presented naked-eye observations for the Earth's spherical shape:
  - Shape of Earth's shadow on the Moon during an eclipse

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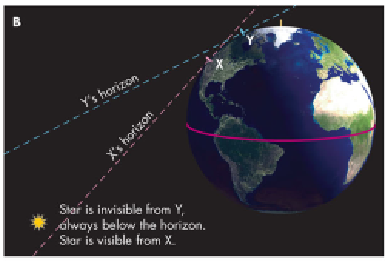
More Observations of a Spherical Earth from Aristotle



- He also noted that a traveler moving south will see stars previously hidden by the southern horizon
- As ships sailed away from port, the hull would disappear first, and tops of sails last.

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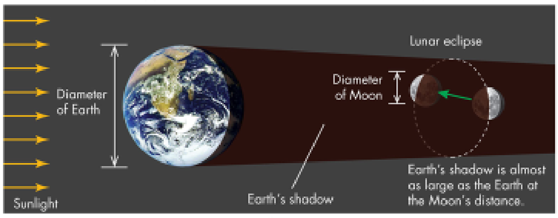
Early Ideas: Distance and Size of the Sun and Moon



NASA

- The sizes and distances of the Sun and Moon relative to Earth were determined by Aristarchus about 75 years before Eratosthenes measured the Earth's size
- Once the actual size of the Earth was determined, the absolute sizes and distances of the Sun and Moon could be determined

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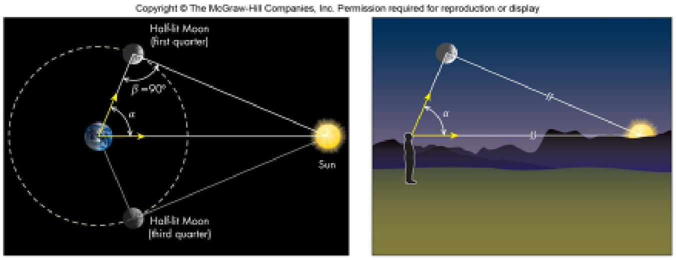
Relative Distance and Size of the Sun and Moon



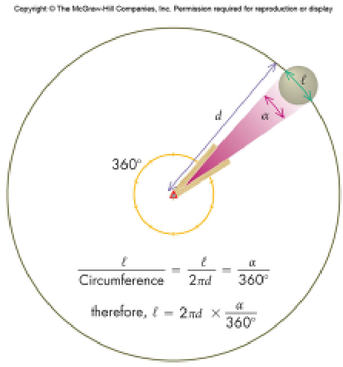
- These relative sizes were based on the ***angular size*** of objects and a simple geometry formula relating the object's diameter, its angular size, and its distance

Aug 21-7:36 AM

Measuring the Diameter of Astronomical Objects

$$l = 2\pi d \times \frac{\alpha}{360°}$$

l – linear size of object
d – distance to object
α – angular size of object



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Aristarchus- Date: *century after Aristotle*

Theory he proposed: *proposed Earth rotated on its axis and revolved around the sun*

Why was his theory rejected? *Most of his work and theory was lost and not well known due to Aristotle's popularity*

Eratosthenes (220 BC)-

Describe his contribution: *calculated Earth's radius and circumference*

How did he work out the mathematical calculations to arrive at his solution? *On the summer solstice measured where sunlight fell to the bottom of a well in Syrene and sun 7 degree south of the zenith at alexander used these measurements and simple geometric calculations*

How accurate was his results? *4% - 14% off depending on the scale of stadia unit*

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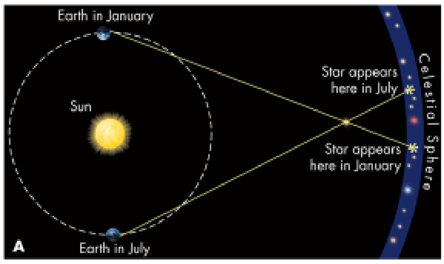
Early Ideas: Arguments for an Earth-centered Solar System



- Aristarchus, realizing the Sun was very large, proposed the Sun as center of the Solar System, but the lack of ***parallax*** argued against such a model

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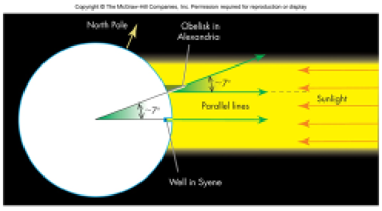
Early Ideas: Eratosthenes

- Eratosthenes (276-195 B.C.) made the first measurement of the Earth's size
- He obtained a value of 25,000 miles for the circumference, a value very close to today's value



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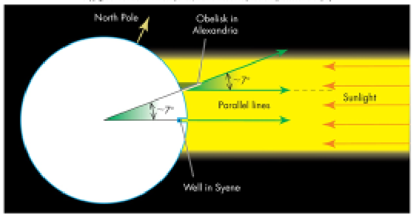
Early Ideas: The Size of the Earth

- He measured the shadow length of a stick set vertically in the ground in the town of Alexandria on the summer solstice at noon, converting the shadow length to an angle of solar light incidence, and using the distance to Syene, a town where no shadow is cast at noon on the summer solstice



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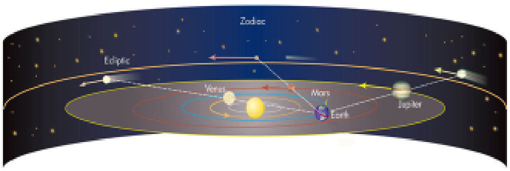
Planets and the Zodiac



- The planets (Greek for "wanderers") do not follow the same cyclic behavior of the stars
- The planets move relative to the stars in a very narrow band centered about the ecliptic and called the ***zodiac***

- Motion and location of the planets in the sky is a combination of all the planets' orbits being nearly in the same plane and their relative speeds about the Sun

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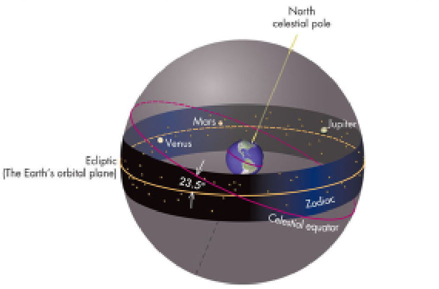
Motion of the Planets

- Apparent motion of planets is usually from west to east relative to the stars, although on a daily basis, the planets always rise in the east



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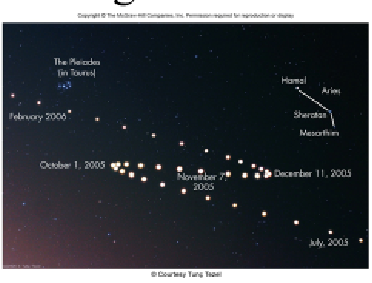
Retrograde Motion



- Occasionally, a planet will move from east to west relative to the stars; this is called ***retrograde motion***
- Explaining retrograde motion was one of the main reasons astronomers ultimately rejected the idea of the Earth being located at the center of the solar system

Aug 21-7:38 AM

Hipparchus (2nd c BC)

What did he invent and what did he discover? *Trigonometry, 1st star catalog, discovered precession*

What is eccentrics? *Sun and moon traveled around in circles with the Earth near but not as their centers, these circles are known as eccentrics*

Aug 21-7:27 AM

Early Ideas: The Geocentric Model

- Because of the general east to west motion of objects in the sky, ***geocentric models*** were developed to explain the motions
- Eudoxus (400-347 B.C.) proposed a geocentric model in which each celestial object was mounted on its own revolving transparent sphere with its own separate tilt
- The faster an object moved in the sky, the smaller was its corresponding sphere
- This simple geocentric model could not explain retrograde motion without appealing to clumsy and unappealing contrivances

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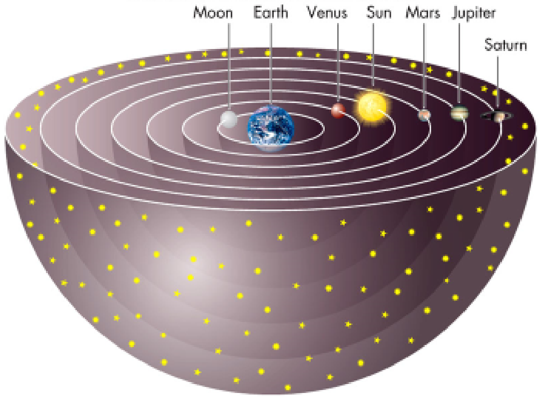
The Earth at the Center of the Universe!



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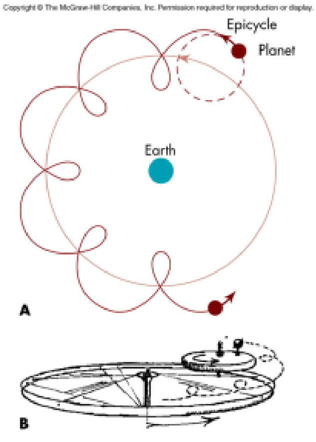
Ptolemy (AD 140)-

What was his contribution to astronomy? *Earth centered heavens moved in uniform circular motion, difficult to try and explain retrograde motion*

Describe his model of the universe. *Used Aristotle mathematical models but still believed earth did not move because they saw no parallax*

Ptolemy of Alexandria: Epicycles

- Ptolemy of Alexandria improved the geocentric model by assuming each planet moved on a small circle, which in turn had its center move on a much larger circle centered on the Earth
- The small circles were called ***epicycles*** and were incorporated so as to explain retrograde motion



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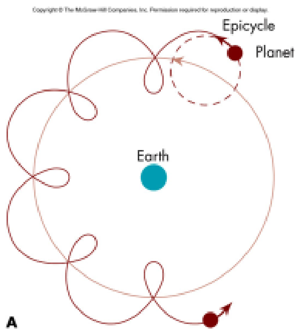
Ptolemy's Success

- Ptolemy's model was able to predict planetary motion with fair precision
- Discrepancies remained and this led to the development of very complex Ptolemaic models up until about the 1500s
- Ultimately, all the geocentric models collapsed under the weight of "Occam's razor" and the ***heliocentric models*** prevailed



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Nicolaus Copernicus-

Proposed what new model of the universe? *The sun was the center, heliocentric model*

Describe the heliocentric model. *Sun centered*

What problems did Copernicus have in announcing his model of the universe? *Challenged Christian beliefs*

What is the difference between the Copernican hypothesis and the Copernicium model? *Hypothesis- heliocentric model, model-arrangement and motion of planets, problem was the idea of uniform circular motion*

Describe how Copernicus explained retrograde motion. *With a heliocentric model, retrograde motion could be explained without epicycles*

Aug 21-7:28 AM

Galileo-

What model of the universe did Galileo support? *heliocentric*

What model did he say he supported in public and why? *He publically supported the church's view to try to keep from being criticized but once he made observations with his telescope he publically defended the heliocentric model*

Galileo did not invent the telescope but what was his contribution to the telescope? *He built another telescope based on information he received from Holland on lenses and a telescope that was built previously*

Aug 21-7:28 AM

Describe each of the following observations made by Galileo:

1. Moon observations- *moon was not perfect it was found to have mountains and valleys, used the shadows to determine the height of the mountains*
2. Milky Way observations- *made of a myriad of stars too faint to be seen unaided*
3. Jupiter observations- *4 new "planets" known today as moons of Jupiter. This discovery suggested that the Earth also moved and this movement would not cause us to leave the moon. Showed that objects did not orbit Earth*
4. Sun observations-*sunspot movement on the sun, reason for the movement of the sunspots is due to the sun's movement. Showed that the Sun was not perfect.*
5. Venus observations- *Venus going through phases like the moon providing evidence that Venus is rotating around the sun further evidence of a heliocentric universe not a geocentric universe*

Aug 21-7:29 AM

What evidence did Galileo put together that supported the Copernican heliocentric model? *Jupiter moon measurement, sunspot motion, Venus phase observations*

Describe the trials of Galileo and the result of those trials. *Trials were fueled with religious concerns and political maneuvering, was interrogated 4x by the inquisition and threatened with torture, told not to hold to or teach or defend Copernicus but never signed a document stating this, Was called to court at 72 to swear to the court ordered belief system but he was sentenced to life imprisonment at his villa till his death at 99.*

Aug 21-7:29 AM

Tycho Brahe-

Describe his first astrological observation in 1562- *Jupiter and Saturn passed near each other nearly merging in the sky. Lead to discovering that the Tables used to measure months and days was in error*

Describe the 1572 “new star” that appeared in the sky and how it was used by Brahe to make an astonishing discovery. *Supernova*

Describe the model of the universe did Brahe develop as a result of not being able to measure parallax.

Since he made measurements of star position accurately this “new star” was above the sphere of the moon and showed that the starry sphere was imperfect and changeable, He stilled held to the belief that the Earth was the center around which the Sun and Moon move, the other planets circle the sun

How did Brahe make his observations of the universe? *Naked eye astronomy, all his instruments were built to measure angles in the sky but no telescopes were available during his time.*

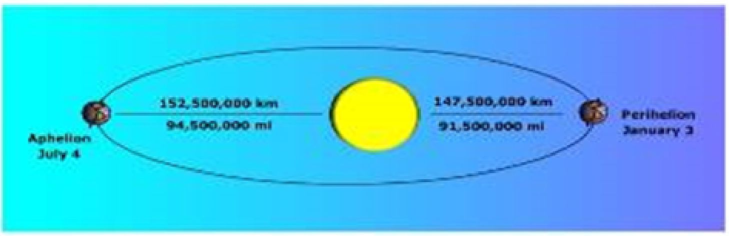
Aug 21-7:29 AM

Begin Here for Kepler

Fill in Notes

Aug 23-9:02 AM

Kepler: Earth's Orbit is:



- An ellipse (not a perfect circle)
- Earth is NOT always the same distance from the sun

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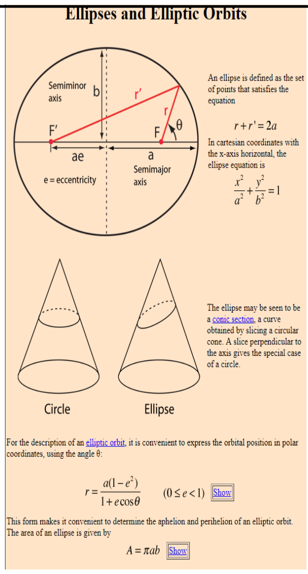

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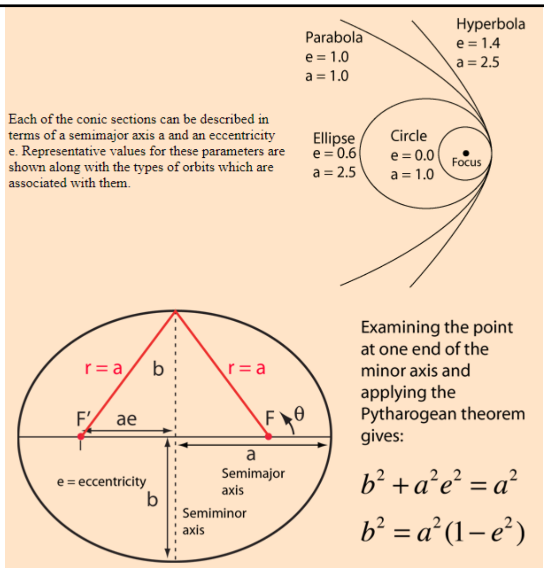

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Shape of the Orbit

In a two-body problem with inverse-square-law force, every orbit is a Kepler orbit.

The eccentricity of this Kepler orbit is a non-negative number that defines its shape.

The eccentricity may take the following values:

The eccentricity may take the following values:

- circular orbit: $e = 0$
- elliptic orbit: $0 < e < 1$ (see ellipse)
- parabolic trajectory: $e = 1$ (see parabola)
- hyperbolic trajectory: $e > 1$ (see hyperbola)

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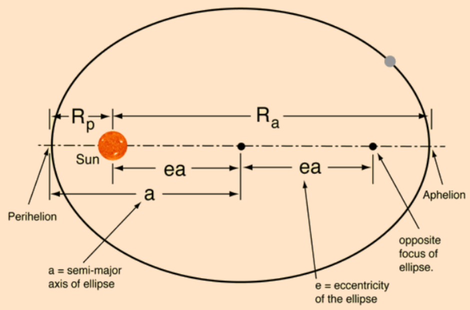
The Law of Orbits

All planets move in elliptical orbits, with the sun at one focus.



$R_a = a(1+e)$ $R_p = a(1-e)$

This is one of Kepler's laws. The elliptical shape of the orbit is a result of the inverse square force of gravity. The eccentricity of the ellipse is greatly exaggerated here.

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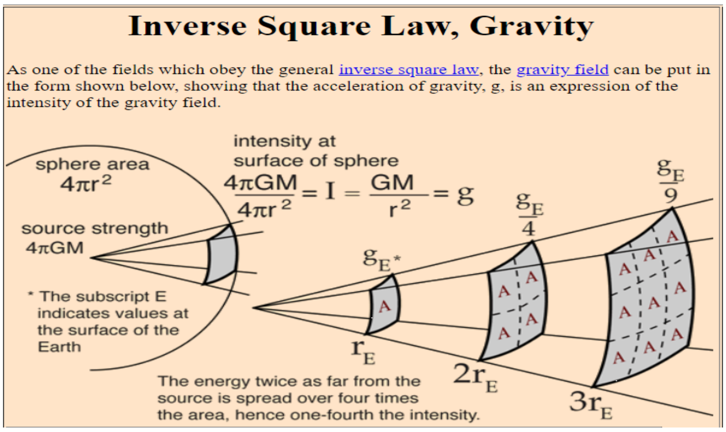

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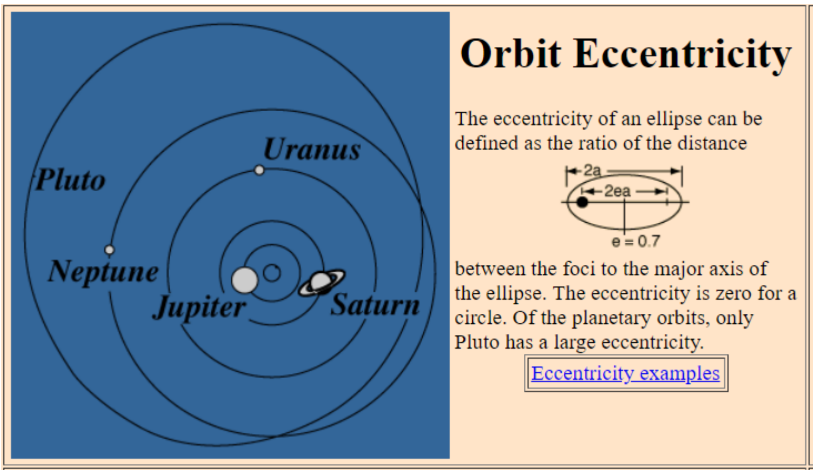

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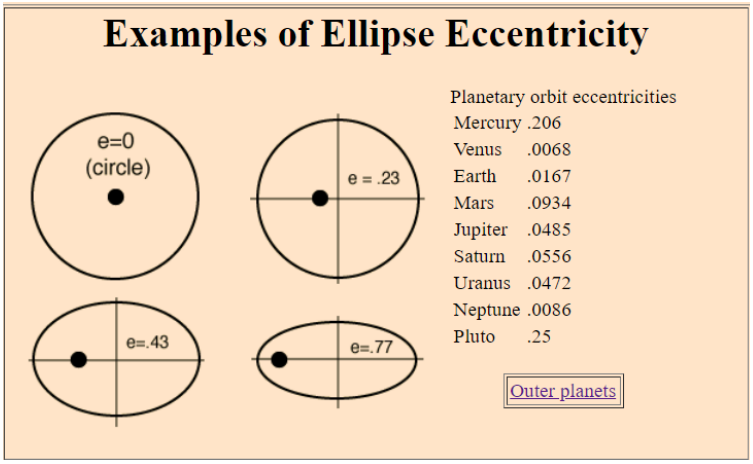

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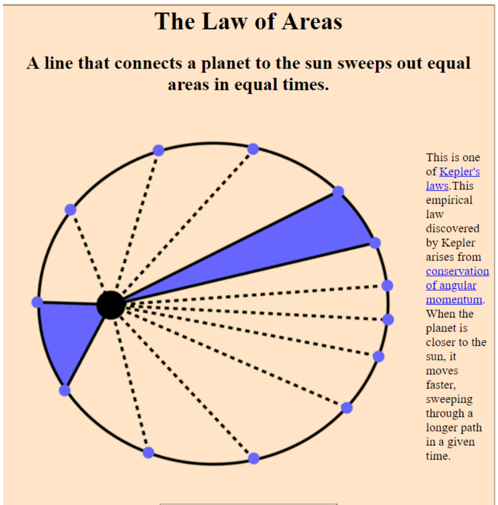

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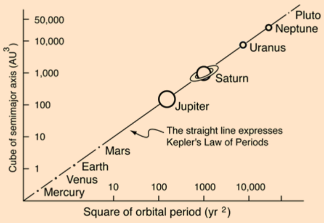
The Law of Periods

The square of the period of any planet is proportional to the cube of the semimajor axis of its orbit.

$$T^2 = \frac{4\pi^2}{GM} a^3$$

This is one of Kepler's laws. This law arises from the law of gravitation. Newton first formulated the law of gravitation from Kepler's 3rd law.



$$T^2 = \frac{4\pi^2}{GM} a^3$$

can be expressed as simply

$$T^2 = a^3$$

If expressed in the following units:

T Earth years

a Astronomical units AU (a = 1 AU for Earth)

M Solar masses $M_\odot$

Then $\frac{4\pi^2}{G} = 1$

Kepler's Law of Periods in the above form is an approximation that serves well for the orbits of the planets because the Sun's mass is so dominant. But more precisely the law should be written

$$T^2 = \frac{4\pi^2}{G(M_1 + M_2)} a^3$$

In this more rigorous form it is useful for calculation of the orbital period of moons or other binary orbits like those of binary stars.

Aug 23-9:10 AM

Data: Law of Periods

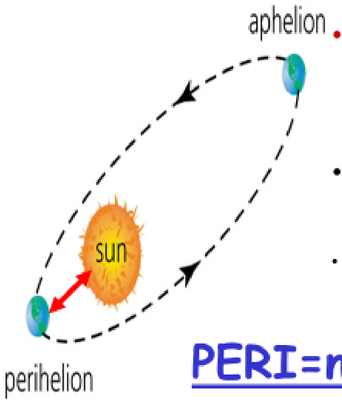
Data confirming Kepler's Law of Periods comes from measurements of the motion of the planets.

Planet	Semimajor axis (10^{10}m)	Period T (y)	T^2/a^3 ($10^{-34}y^2/m^3$)
Mercury	5.79	0.241	2.99
Venus	10.8	0.615	3.00
Earth	15.0	1	2.96
Mars	22.8	1.88	2.98
Jupiter	77.8	11.9	3.01
Saturn	143	29.5	2.98
Uranus	287	84	2.98
Neptune	450	165	2.99
Pluto	590	248	2.99

The quantity T^2/a^3 depends upon the sum of the masses of the Sun and the planet, but since the mass of the Sun is so great, adding the mass of the planet makes very little difference.

Aug 23-9:11 AM

PERIHELION

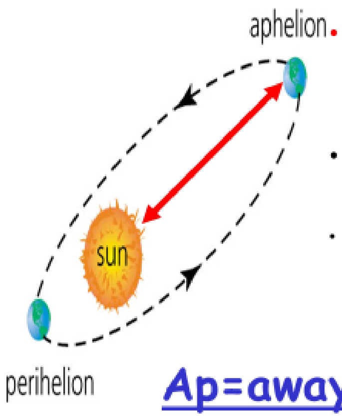


- Earth is closest to the sun
- Occurs on: Jan 3rd
- 147 million km away = (91.34 million miles)

PERI=near Helio=Sun

Aug 23-7:29 AM

APHELION

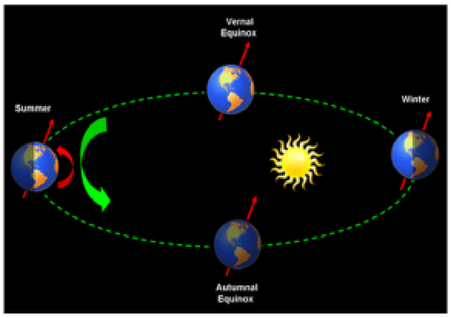


- Earth is farthest from the sun
- Occurs on: July 4th
- 152 million km away= (94.45 million miles)

Ap=away Helio=Sun

Aug 23-7:29 AM

How does this relate to the seasons?

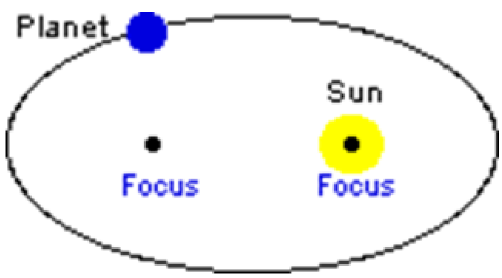


- During which season are we closest to the sun?
- Farthest?

Aug 23-7:29 AM

Kepler's Laws of Planetary Motion

- 1st law : planets orbit the sun in a path called an ellipse (oval shape)

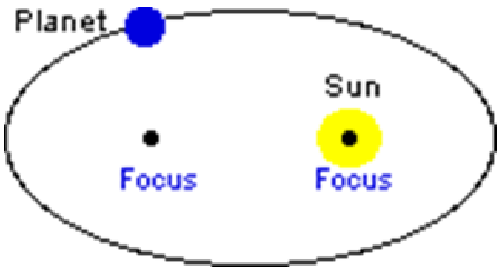


Smithsonian Animation:
http://howthingsfly.si.edu/flight-dynamics/kepler%E2%80%99s-laws-orbital-motion

http://astro.unl.edu/classaction/animations/renaissance/kepler.html

Aug 23-7:30 AM

- Shape of ellipse is determined by 2 points (called a focus)
  - Sun is at one focus, nothing at the other



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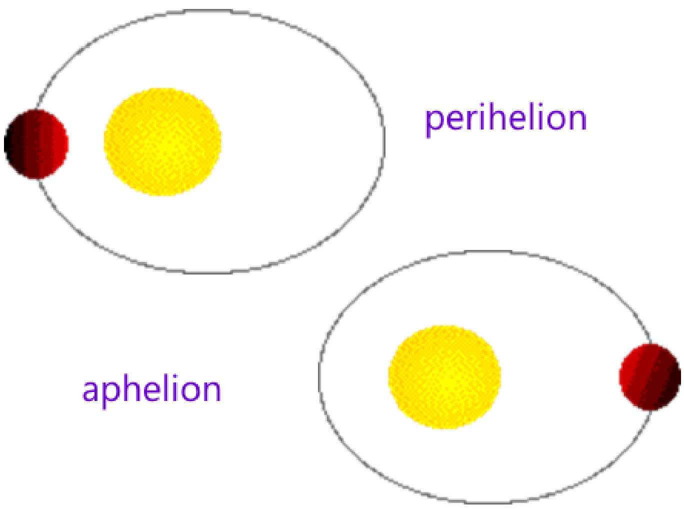

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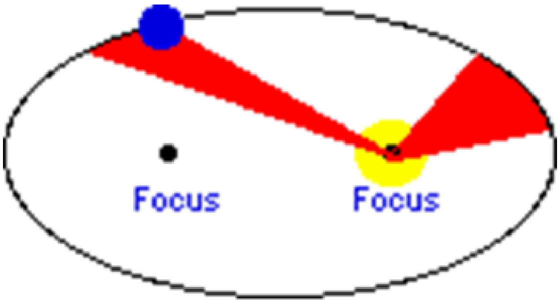
- 2nd law: planets move **fastest when they are closest** to the sun in their orbits, and slower when far away



"Equal areas in equal time"

Aug 23-7:30 AM

Why does a planet move faster when closer to the sun?

The **closer** a **planet** is to the **Sun**, the stronger the **Sun's** gravitational pull on it, and the **faster** the **planet moves**. The farther it is from the **Sun**, the weaker the **Sun's** gravitational pull, and the slower it **moves** in its orbit.

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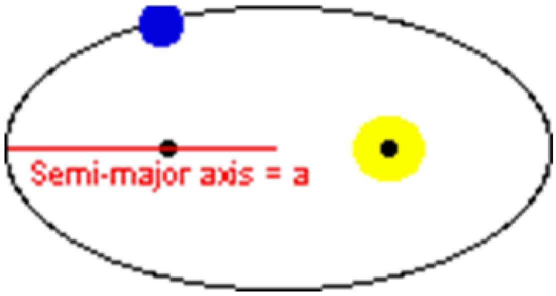
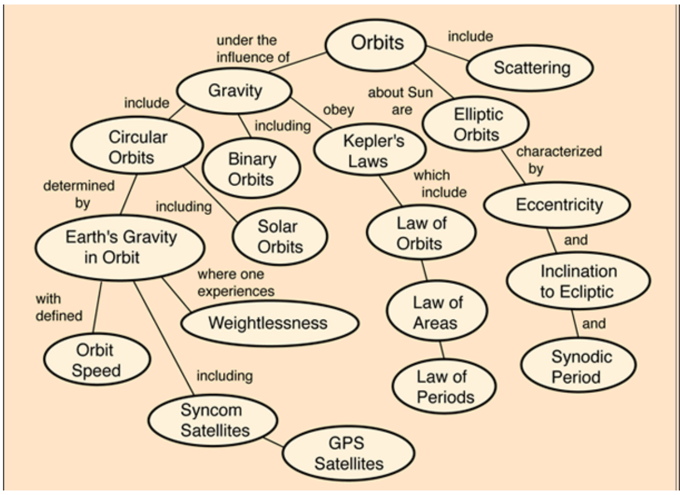
- 3rd law: the **farther away** a planet orbits, **the longer** the planet **takes to revolve** around the sun



"The greater a planet's distance is to the sun, the longer it takes to complete its orbit around the sun"

Aug 23-7:31 AM



CONCEPT MAP FOR ORBITS

Aug 23-9:18 AM

Complete the Kepler Law

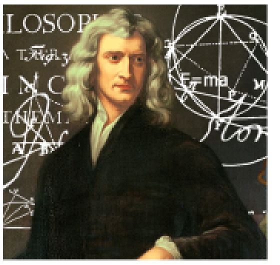
online Computer Simulation

Aug 23-9:01 AM

Gravity and Newton

Aug 23-7:38 AM

Sir Isaac Newton



- Figured out how planets stay in orbit around the sun
  - Gravity holds them close to the sun
  - Inertia makes them want to move in a straight line away from the sun

(Combination of these two forces results in the planet remaining in orbit)

Aug 23-7:31 AM

Newtons Laws

- Gravity –
  - force of attraction between two objects
    - Force decreases with distance
    - The greater the mass of an object, the greater the gravitational force
- Inertia-
  - an object in motion will not change speed or direction unless acted on by an outside force
  - An object at rest will stay at rest

Aug 23-7:31 AM

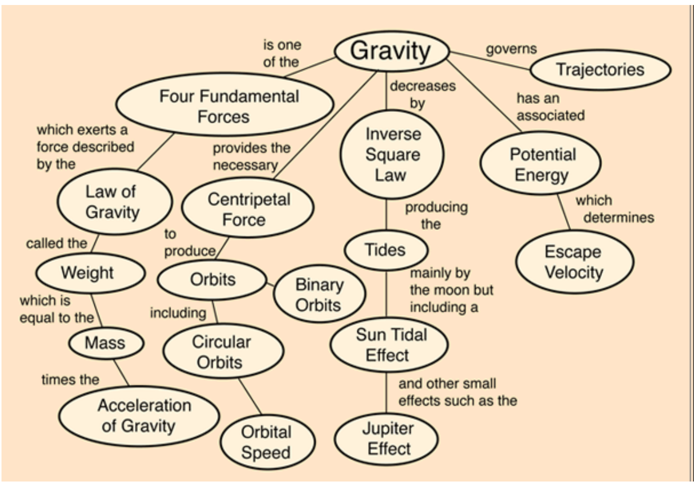
Gravity

Gravity is the weakest of the four fundamental forces, yet it is the dominant force in the universe for shaping the large scale structure of galaxies, stars, etc. The gravitational force between two masses m_1 and m_2 is given by the relationship:

$$F_{gravity} = \frac{Gm_1 m_2}{r^2} \quad \text{where} \quad G = 6.67 \times 10^{-11}\ N\, m^2/kg^2$$

This is often called the "universal law of gravitation" and G the universal gravitation constant. It is an example of an inverse square law force. The force is always attractive and acts along the line joining the centers of mass of the two masses. The forces on the two masses are equal in size but opposite in direction, obeying Newton's third law. Viewed as an exchange force, the massless exchange particle is called the graviton. From Einstein's treatment in general relativity, gravity is associated with a curvature of space-time and changes in mass configuration can produce gravitational waves.

Aug 23-9:17 AM



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Aug 23-9:16 AM