A. Most everything we know about the universe comes from the study of energy traveling through space in the form of “radiation”.

1. Radiation--(electromagnetic radiation)

   energy emitted by atoms which make up distant bodies (stars/galaxies) traveling 300 000 km/sec through space.

   a) electromagnetic spectrum--all of the kinds of radiation together. The range of wavelengths, from radio waves to gamma rays.
B. ASTRONOMY--is the study of all matter and energy in the universe

C. A Survey of the Universe

1. The Universe--everything that exists--made up of thousands of clusters of galaxies.

2. Galaxies--swarms of billions of stars.

3. Globular Star Clusters--a halo of stars that makes up the center of most galaxies (including ours). Over a hundred globular clusters are members of our Milky Way Galaxy.

4. Open Star Clusters--groups of stars inside our galaxy, mostly in the spiral arms. The Sun is located in an open cluster.
5. **Nebulae** -- clouds of dust & gas in space that are star forming areas formed from exploding stars.

6. **Star** -- ball of gas that shines or has shone because of nuclear reaction in its interior (mostly hydrogen).

7. **Sun** -- the star orbited by Earth. A hydrogen sphere 1.4 million km in diameter. The sun is the center of the solar system.

8. **Planets** -- a solid (or partially gas and liquid) body orbiting around a star but too small to generate energy by nuclear reactions.

9. **Solar System** -- the sun and its family, including nine planets and their satellites.
10. **Satellites**--any small body orbiting a larger body.

11. **Asteroids**--a rocky or metallic interplanetary body (usually larger than 100 m in diameter).

12. **Comets**--ice-rich interplanetary bodies that orbit the sun.

13. **Earth**--one of nine planets that orbit the sun. Its orbit is an average of 150 million km from the sun.

14. **Moon**--the Earth’s only satellite. 384 000 km away.
EARLY ASTRONOMY DEALT WITH PRACTICAL THINGS SUCH AS:

1. Keeping Time
2. Marking the arrival of the seasons.
3. Predicting eclipses of the Sun and the Moon.

A. EGYPTIAN and OTHER EARLY ASTRONOMERS

1. Hunters 30 000 years ago probably used certain celestial cycles to help them hunt & acquire food.
2. **Constellations**—figures in the sky—were recorded by the Sumerians as far back as 2000 B.C.

3. The Egyptians noticed that they could base a calendar on **Sirius**, the brightest star in the sky.

   a. **Helical Rising**—of a star occurs on the first day each year when the star can be seen just before dawn.

   b. **Helical Setting**—occurs on the last day of the year when the star can be seen at dusk.
B. GREEK ASTRONOMY: THE EARTH at the CENTER

1. In ancient times, five planets were known: Mercury, Venus, Mars, Jupiter, and Saturn.

   a. **Ecliptic**--the apparent path of the sun across the sky. The planets & moon appear to move on or near this ecliptic.

   b. **Retrograde Motion**--the apparent backward motion of a planet with respect to the background stars.
2. EARLY GREEK ASTRONOMY  
(600 B.C.---A.D. 150)

a. Thales (636--546 B.C.) was one of the first known Greek thinkers, he predicted an eclipse that stopped the battle between warring Greek factions in 580 B.C.

b. Plato (400 B.C.) reasoned that astronomy contributed to the civilization of humanity.

c. Aristotle (350 B.C.) universe was spherical and finite, with Earth at the center.

1. The universe was made up of a set of spheres.

2. The stars were in the outer most sphere.

3. The Prime Mover was beyond the outer sphere.
• Aristotle was right about several important astronomical ideas:

1. He thought the moon was spherical.

2. He argued that the sun was farther away than the moon.

3. He thought the Earth was spherical.

d. Erathostenes (200 B.C.) determined the size of Earth using angular geometric relations to measure Earth size.
e) **Ptolemy (A.D. 150)**—best known contribution was a method for predicting the positions of the sun, moon, & planets (like Aristotle he incorrectly placed the Earth in the center)

- He placed the Earth in the center then the moon, Mercury, Venus, the Sun, Mars, Jupiter, & Saturn.
- He imagined the planets on small orbits, called epicycles.
- The center of each small orbit moved around Earth on a larger orbit called a **deferent**.
The Greeks reasoned the Earth was in the center because they could not see stellar parallax

e) **Parallaxes**—a small angular shift in a star’s apparent position due to the Earth’s motion around the sun. (can be used to measure stellar distance)
C. Nicolaus Copernicus (1473-1543)—(the major credit for the breakthrough in our understanding of the solar system belongs to Copernicus)

  a) a Polish astronomer—he is credited with proposing the heliocentric or sun-centered solar system.

• His theory still contained only circular orbits, ∴ he still needed to use epicycles to explain the retrograde motions of some planets with respect to the background stars
D. **Tycho Brahe (1546-1601)**—a Danish nobleman, who set up an observatory on an island off the mainland of Denmark.

   a) Before the telescope—Tycho invented and used giant instruments to catalogue the positions of planets and stars

   b) **Kepler (25 years old)**—worked with Brahe the last 10 months he lived & took Brahe’s data after he died.
E. **Archaeoastronomy**—investigations that attempt to link archaeology & astronomy.

- The main line of astronomy that has led to today’s conception of the universe was largely European. There is currently an increase in the study of the extent of astronomical understanding in other parts of the world.

- We will deal here with only 3 examples
E-1 Stonehenge

2. 25 tons each forming a circle 30 meters in diameter.
3. Built in 3 parts dating from 2700BC—1700BC.
4. Used to mark summer & winter solstices.
5. To predict eclipses.
6. To mark the northern & southern most moonsets & moonrises.
E-2. **Mayan Astronomy**

1. Lived in what is now the Yucatan Peninsula of Mexico & Guatemala.

2. Their cities & buildings are aligned to astronomical phenomena.

3. Their calendar was set by the sun & moon.

4. Also based on the rising & setting of Venus.
E-3. **Native American Astronomy**

1. Recent discoveries show Native Americans in the American west were interested in astronomy.

2. Cave painting in the S.W.U.S. show they probably observed the explosion of a star—AD 1054—Taurus A or the Crab Nebula in Taurus the Bull.

3. **Medicine Wheels**—lines of stones shaped like a wagon wheel in which major points extend toward summer & winter solstices’ sunrise & sunsets. * also point toward certain stars’ helical rising & settings.
4. Caves carved in stone, have been located, which allows light to past through during solstices.

5. Calendar Sticks—wooden sticks showing detailed astronomical record-keeping of the Winnebago Native Americans 1600’s—1800’s.
THE ORIGIN of MODERN ASTRONOMY

4.4 Johannes Kepler (1571-1630)

• **Kepler’s First Law (1609)**—the planets orbit the Sun in **ellipses**, with the Sun at one focus.

  a) *circle*—a curve with every point an equal distance from the center.

  b) *Ellipse*—a curve with two points called its foci (singular, *focus*) instead of one center point.

  c) For any point on an ellipse, the sum of its distance from the 2 foci is the same.

  d) The farther apart the foci are—the more eccentric the orbit is.
• The 1\textsuperscript{st} law explains that the distance between a planet and the sun is always changing—1/2 of its orbit the distance from the sun is increasing & the other 1/2 the of its orbit the distance is decreasing.
• Kepler’s Second Law (1609)—states that the line joining the Sun and a planet sweeps through equal areas in equal times. (law of equal areas)

• The 2nd law explains that in order for the radius vector to cover equal areas in equal times—the planet must move faster when nearer the sun & moves more slowly when it is farther away.
• Kepler’s Third Law (1618)—the ratio of the squares of the periods of revolution of any two planets is equal to the ratio of the cubes of their average distances from the sun.

• the 3\textsuperscript{rd} law explains—the farther a planet is from the sun, the longer its period of revolution.

a) period—the length of time a planet takes to orbit the sun.

b) Astronomical Unit (AU)—the average distance from the Earth to the sun
c) Example—3rd law: What is the period of Jupiter, if its distance from the sun is 5.2 AU

\[
\frac{(Jupiter's Period)^2}{(Earth's Period)^2} = \frac{(Jupiter's Distance)^3}{(Earth's Distance)^3}
\]

\[
\frac{(X)^2}{1^2} = \frac{(5.2 \text{ AU})^3}{(1 \text{ AU})^3}
\]

\[
(X)^2 = 140.6 \text{ years}
\]

Jupiter's period = 12 years
d) 2 reasons the 3rd law works

1. the orbits are larger the farther the planet is from the sun.

2. also a planet farther from the sun moves slower than a planet nearer the sun.

- Earth’s speed = 30 km/s
- Mercury’s = 48 km/s
- Pluto’s = 5 km/s
3.2 Galileo Galilei (1564-1642)

1. Perfected the telescope by the late 1609.

2. He found four satellites revolving around Jupiter—thus supplying proof that at least some bodies do not revolve around the Earth.

3. He mapped our moon with his telescope.

4. He also discovered that Venus went through an entire series of phases—another piece of evidence proving that the Earth was not in the center.

• If the Ptolemaic theory were true, Venus would always be a crescent
3.3 **Isaac Newton** (1642-1727) **English**—born the year Galileo died.

1. He was the first to realize that the same law that describes how objects fall on Earth describes how objects fall far out in space.

2. The Moon is always falling toward Earth. At the same time it moves forward in space in its orbit.
3. **Law of Universal Gravitation**—the gravitational force between two bodies is equal to the product of multiplying their mass and divided by the distance between their centers squared.

\[ F = G \frac{Mm}{R^2} \]

\[ G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{Kg}^2 \]
Law of Universal Gravitation continued:

\[ a) \text{ If the bodies' mass doubles—the force between them doubles.} \]

\[ b) \text{ If the distance between their centers doubles, the force drops by a factor of 4.} \]
4. **Newton’s Laws of Motion**

   a) **The First Law of Motion**—a body at rest will remain at rest, & a body in motion will continue in motion with a constant speed in a straight line as long as no external force acts on it.

   **inertia**—the tendency of an object to resist any change in its velocity. This is a property of all matter.
b) **The Second Law of Motion**—a larger mass requires a larger force to give it the same acceleration obtained for a smaller mass and a smaller force.

\[ \text{Force} = \text{Mass} \times \text{acceleration} \]

c) **The Third Law of Motion**—for every action there is an equal and opposite reaction. This makes rockets work.