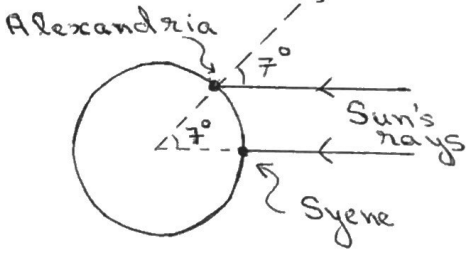
Some Important Discoveries of Ancient Astronomers

- Moon is spherical
  - Curvature of the lunar terminator changes with the phase of the moon. [Pythagoreans]

- Earth is spherical
  - Circular shadows during lunar eclipses [Pythagoreans]
  - As you travel north you see more stars in the northern part of the sky while southern stars disappear below the horizon [Aristotle]

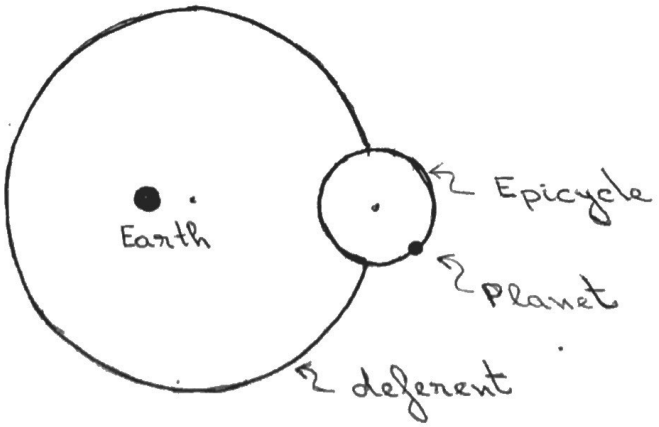
- Earth is bigger than the moon; Sun is bigger than the earth.
  [Aristarchus; he also believed that the earth revolved around the sun]

- Measurement of the Earth's diameter [Eratosthenes]
  Distance / Circumference = 7° / 360°
  Circumference = π x diameter



- Precession [Hipparchus]
  - The wobbly motion of the earth's rotation axis due to the gravitational influence of the moon.
  - The vernal equinox moves along the ecliptic east to west
  - Rate of precession = 50" / year
  - Period of precession = 26,000 years
  - Effect of precession - changes right ascension and declination

- Ptolemy's Model



Modern Astronomy

-Nicolaus Copernicus (1473 - 1543)

- De Revolutionibus (On Revolutions, 1543)
- Heliocentric model (sun - centered)
  Orbits of planets were circular
- Simple explanation of retrograde motion.

- Tycho Brahe (1546 - 1601)

- Precise observations of the positions of stars and planets from his observatory Uraniborg
- Detected no stellar parallax, hence concluded that the earth was stationary.

- Johannes Kepler (1571 - 1630)

Laws of Planetary Motion

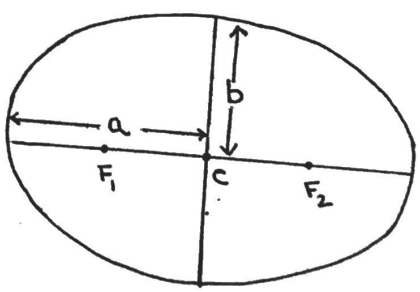
I : The orbit of a planet is an ellipse with the sun at one foci.

II : The line joining a planet to the sun sweeps out equal areas in equal times. [Law of equal areas]

III : (Sidereal Period)^2 α (Semi-major axis)^3

$P^2 \alpha a^3$ [Harmonic Law]

a = semi-major axis
b = semi-minor axis
F_1, F_2 = Focus
c = center
Eccentricity $e = (1 - b^2/a^2)^{1/2}$
e = 0 for a circle
e = 1 for a straight line



- Galileo Galilei (1564 - 1642)
    - Departure from Greek thinking - start with assumptions and build a rational system (deductive method)
    - Galileo's method - start with observations and build a rational system. (empirical method)
    - Galileo's discoveries published in
        - Starry Messenger
        - Dialogue of the Two Chief World Systems
    - Astronomical discoveries
        - Four moons of Jupiter
        - Phases of Venus
        - Craters on the moon
        - Sunspots
        - Milky Way composed of stars

- Issac Newton (1642 - 1727)
    - Laws of Motion

        I : A body at rest stays at rest and a body in uniform motion stays in uniform motion unless compelled by an external force to act otherwise. [Law of inertia]

        II : Force = mass x acceleration

        III : For every action there is an equal and opposite reaction.

    - Law of Universal Gravitation

        Every particle in the universe attracts every other particle with a force proportional to the product of their masses and inversely proportional to the square of the distance between them.

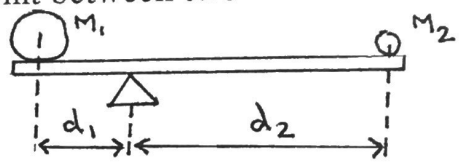
        $F = G\ (m_1 \times m_2) / d^2$

- Surface gravity of a planet (acceleration due to gravity) :

$g = GM / R^2$

- Center of Mass (Barycenter) : The balance point between two masses :

$M_1 \times d_1 = M_2 \times d_2$



- Newton's modification of Kepler's 3rd law :

$(M_1 + M_2) P^2 = (4 \pi^2 / G) a^3$

If M_1 and M_2 are measured in terms of the sun's mass

P is measured in years

a is measured in astronomical units

Then $(M_1 + M_2) P^2 = a^3$

- Bound orbits
  - Circular or elliptical
  - Kinetic Energy < Potential Energy
  - $v_{circ} = (G M / R)^{1/2}$

- Unbound orbits
  - Parabolic or hyperbolic
  - Kinetic Energy > Potential Energy
  - $v_{esc} = (2 G M / R)^{1/2}$

- Tidal Force : Differential Gravitational Force

- Tidal Force due to a mass M on a mass of size L and at a distance R is proportional to $(M \times L) / R^3$