Chapter 2: Orbits and Gravity

2.1 The Laws of Planetary Motion

Tycho Brahe (1546-1601)

- Last of the great pre-telescopic astronomers
- Member of Danish nobility
- Tycho lost part of his nose in a duel with another student in 1566. For the rest of his life he wore a metal insert over the missing part.
- Made systematic astronomical observations
  - Among these, observations of an exploding star (although he had no idea what he was seeing)

2.1 The Laws of Planetary Motion

Tycho Brahe (1546-1601)

- That discovery caught the attention of the Danish king, Frederick II
- King funded Brahe to build an astronomical observatory

2.1 The Laws of Planetary Motion

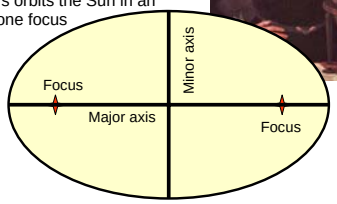
Tycho Brahe (1546-1601)

- Made continuous records of the positions of the Sun, Moon, and planets for more than 20 years
  - Found that planet positions varied from those in tables based on geocentric system
- After Frederick died, Brahe lost his political clout and moved to Prague
  - Became court astronomer to Emperor Rudolph of Bohemia
- There, he also found an able assistant: Johannes Kepler

2.1 The Laws of Planetary Motion

Johannes Kepler (1571-1630)

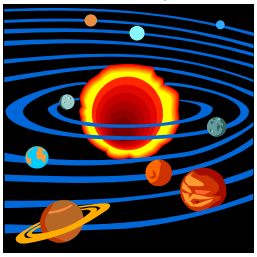
- After Tycho's death, Kepler worked with Tycho's records and began to study planetary motion
  - Most extensive study was motion of Mars
- Discovered that Mars orbits the Sun in an ellipse, with Sun at one focus
- Vocabulary:
  - Major axis
  - Minor axis
  - Focus
  - Eccentricity



2.1 The Laws of Planetary Motion

Kepler's Laws of Planetary Motion

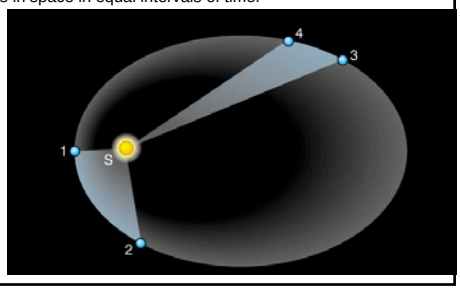
- 1st Law: Each planet moves around the Sun in an ellipse with the Sun at one focus.



2.1 The Laws of Planetary Motion

Kepler's Laws of Planetary Motion

- 2nd Law: The straight line joining a planet and the Sun sweeps out equal areas in space in equal intervals of time.
  - Fig 2.5



2.1 The Laws of Planetary Motion

Kepler's Laws of Planetary Motion

- 3rd Law: The squares of a planet's period of revolution is equal to the cube of the semimajor axis of its orbit.

  period^2 = distance^3 or $p^2 = d^3$

  - Example: Mars takes 1.88 years to orbit the Sun, so:

    p = 1.88 years

    (1.88)(1.88) = 3.53 = d^3

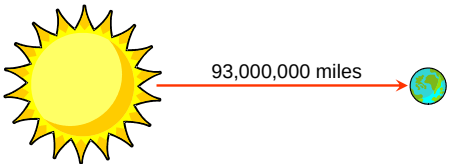
    where d is in **Astronomical Units**

    cube root of 3.53 = 1.52 AU

2.1 The Laws of Planetary Motion

Term to learn: <u>Astronomical Unit</u> (AU)

1 AU = average distance between Earth and Sun



2.2 Newton's Great Synthesis

Isaac Newton (1643-1727)

Three Laws of Motion

1. Every body continues to do what it is already doing – either at rest or in motion – unless it is changed by an external force
   - That's why we need seatbelts!

2.2 Newton's Great Synthesis

Isaac Newton (1643-1727)

Three Laws of Motion

2. The change in motion of a body is proportional to the force acting on it, and is made in the direction in which the force is acting
   - Slingshot versus a cannon

2.2 Newton's Great Synthesis

Isaac Newton (1643-1727)

Three Laws of Motion

3. To every action, there is an equal and opposite reaction
   - Recoil of gun
   - Rocket engine: works best in vacuum

2.2.3 Mass, Volume, and Density

Terms to learn:

1. Mass
   - _____
2. Volume
   - _____
3. Density
   - _____

2.2.4 Angular Momentum

What is *Momentum*?

_____

_____

_____

Momentum can be defined as "_____." All objects have mass; so if an object is moving, then it has _____ - it has its _____. The amount of momentum which an object has is dependent upon two variables: _____ and _____.

- An object has a large momentum if either its _____ or its _____ is large.

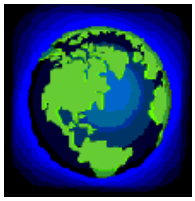
2.2.4 Angular Momentum

What is *Angular Momentum*?

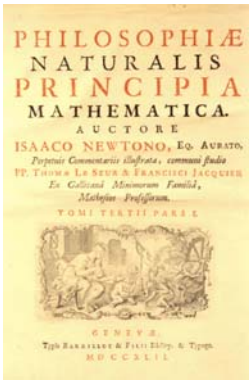
_____

_____

_____



2.3 Universal Gravity


PHILOSOPHIÆ
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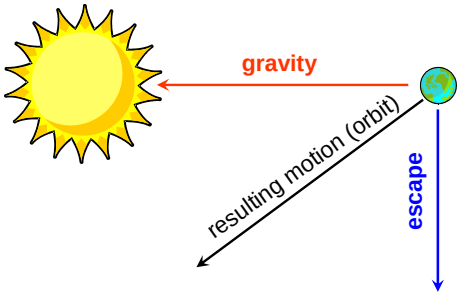
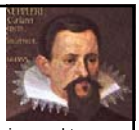
ISAACO NEWTONO, Eq. Auratо,

2.3 Universal Gravity

- Newton's laws say that an object will continue to move in a straight line unless influenced by an external force.



2.3 Universal Gravity



Remember Kepler's 3rd laws of planetary motion?

- 3rd Law: The squares of a planet's period of revolution is equal to the cube of the semimajor axis of its orbit.

  period^2 = distance^3 or $p^2 = d^3$

Newton showed that it actually works out to be:

$$D^3 = (M_1 + M_2) \times P^2$$

Where M_1 is the mass of the Sun (= 1 on this scale) and M_2 is the mass of a given planet (negligible compared to the Sun)

2.4 Orbits in the Solar System

Terms to learn:

1. Perihelion

- _____

2. Aphelion

- _____

3. Perigee

- _____

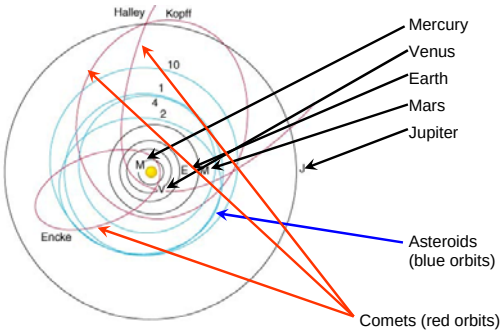
4. Apogee

- _____

5. Semimajor axis

- _____

2.4 Orbits in the Solar System



2.4 Orbits in the Solar System

Table 2.2, page 52

TABLE 2.2 *Orbital Data for the Planets*

Planet	Semimajor Axis (AU)	Period (yr)	Eccentricity
Mercury	0.39	0.24	0.21
Venus	0.72	0.62	0.01
Earth	1.00	1.00	0.02
Mars	1.52	1.88	0.09
(Ceres)	2.77	4.60	0.08
Jupiter	5.20	11.86	0.05
Saturn	9.54	29.46	0.06
Uranus	19.19	84.07	0.05
Neptune	30.06	164.80	0.01
Pluto	39.60	248.60	0.25

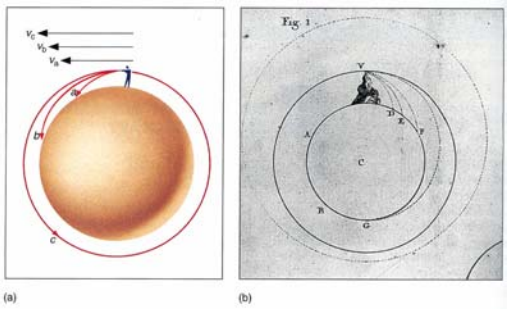
2.5 Motions of Satellites and Spacecraft

Thought question:

- Why do astronauts float around in the Shuttle instead of falling?
  a. the Shuttle is so far from the Earth, gravity is negligible
  b. the Shuttle's gravity balances the Earth's, so that the net gravity is zero
  c. the Shuttle is falling around the Earth (and everything aboard is in free fall)
  d. the Shuttle has an antigravity device on board, developed by NASA
  e. the rules Newton developed for gravity only hold on Earth, not once you get into space

2.5 Motions of Satellites and Spacecraft

Figure 2.11, page 54



2.6 Gravity with More than Two Bodies

The Discovery of Neptune: September 23, 1846

John Couch Adams

Urbain Leverrier

Homework

- Chapter 2, questions 6, 7