

ASTR 1120, Accelerated Solar System Astronomy Midterm 1 Study Sheet

Reading: Chapters 1-2.

I. SCALE OF THE UNIVERSE

1. Powers of 10

- $10^0 = 1$
- $10^3 = 1,000$
- $10^6 = 1,000,000$
- $10^9 = 1,000,000,000$
- $10^{12} = 1,000,000,000,000$
- $10^{15} = 1,000,000,000,000,000$

Kilo
Mega
Giga
Tera

2. Our place in the universe

- Local Supercluster: $\sim 10^{24-25}$ m.
- Local Group: $\sim 10^{22-23}$ m
- The Milky Way Galaxy: $\sim 10^{21}$ m.
- The Solar System: $\sim 10^{13}$ m.
- Earth: $\sim 10^7$ m.
- Colorado: $\sim 10^6$ m.
- Boulder: $\sim 10^4$ m.
- Duane Physics: $\sim 10^2$ m.
- Mailbox: $\sim 10^{-1}$ m.

3. Units of distance:

- meter: ~ 39 inches or 10% larger than a yard.
- km: 1000 m
- cm: 0.4 inch
- **Astronomical Unit or A.U.:** The distance between Sun and Earth; 150,000,000 km, or 1.5×10^{11} m. We use AU for distances within the solar system.
- **Light year:** The distance light travels in one year. $\sim 10^{16}$ m. We use light years for distances between stars.

4. Velocity, Distance, and Time

$$v = \frac{x_2 - x_1}{t_2 - t_1}$$

5. Acceleration:

$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

6. Ratios

- Ratios allow us to envision the vast scales of the universe.
- Example: If the sun were the size of a grapefruit, how large would the earth be?

$$\frac{\text{Object1}_{\text{ModelSize}}}{\text{Object1}_{\text{ActualSize}}} = \frac{\text{Object2}_{\text{ModelSize}}}{\text{Object2}_{\text{ActualSize}}}$$

7. Space and Time

- Know that the speed of light is 3×10^8 m/s.
- Looking at far away galaxies is also looking back in time.
- Example: Light takes 1 billion years to travel 1 billion light-years.
- Example: Light takes 1 million years to travel 1 million light-years.

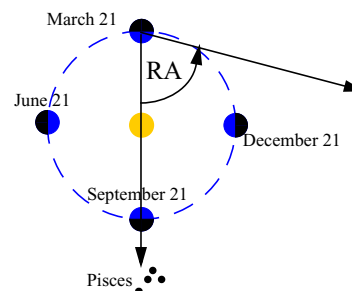
II. THE NIGHT SKY

1. Constellations.

- The most common way to find stars.
- You must know 10 of the 20 brightest stars in the sky and their constellation (see tables in the back of the text).

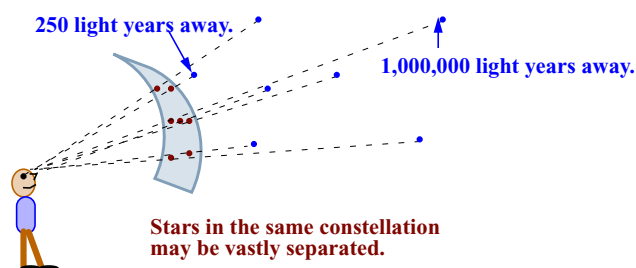
2. Locating Objects in the Sky

- **Right Ascension** is the angle counterclockwise from Vernal Equinox along Earth's equatorial plane.
- **Declination** is the angle above Earth's equatorial plane.



3. Projection

- Stars in a constellation may be vastly separated.



III. RELATIVE MOTION (OUTLINE)

1. The Earth's Rotation (1 Day)

- Day/Night cycle.
- Moonrise/set.
- Stellar rising/setting.

2. The Moon's Orbit (~1 Month)

- Phases of the moon (above).
- Solar/Lunar eclipses (see later)

3. Revolving about the sun (1 Year).

- Changes in the night sky - Zodiac constellations.
- Seasons (Tilt of the Earth's axis).
- Stellar parallax.

4. Planetary, comet, and asteroid orbits (0.24 year to 248 years).

- Changes in the night sky - position of the planets.
- Apparent retrograde motion.
- Cometary light shows.
- Meteor showers.

5. Precession (26,000 years)

- Position of the "North Star".
- Changes in the night sky - signs of the Zodiac.

6. The orbit of the Milky Way (230,000,000 years)

- A new look at the universe.

7. The motion of the Galaxies

- The expanding universe

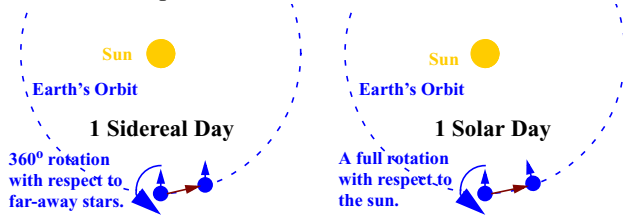
RELATIVE MOTION I

1. The Tilt of the Earth's Spin Axis

- The Earth's tilt axis is 23.5° from perpendicular to its orbital plane.
- The axis points nearly directly at Polaris.

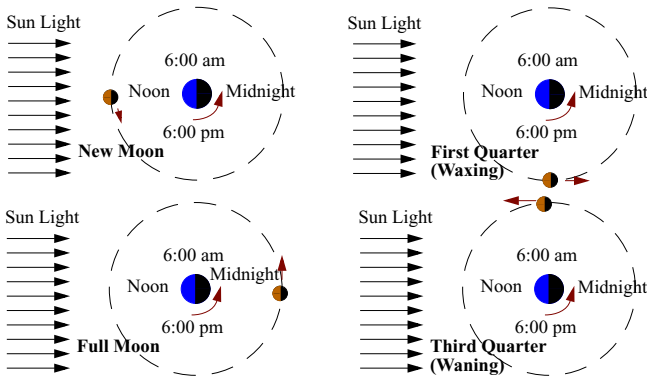
2. Solar Day and Sidereal Day

- A solar day is ~ 4 minutes longer than a sidereal day; extra rotation is required due to the orbital motion.



RELATIVE MOTION II

1. Phases of the Moon



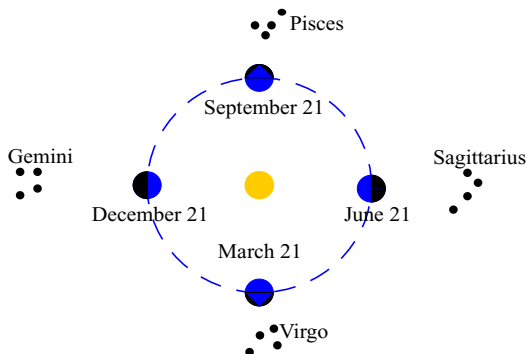
2. The Moon's Orbit

- Ecliptic Plane** - The plane of Earth's orbit about the sun.
- Lunar Orbit** - Tilted 5° with respect to the ecliptic plane.
- Nodes** - Points of the moon's orbit in the ecliptic plane.

RELATIVE MOTION III

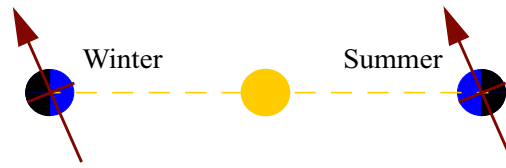
1. Changes in the Night Sky - Zodiac Constellations.

- Different Zodiacal constellations come into view at different times of the year.



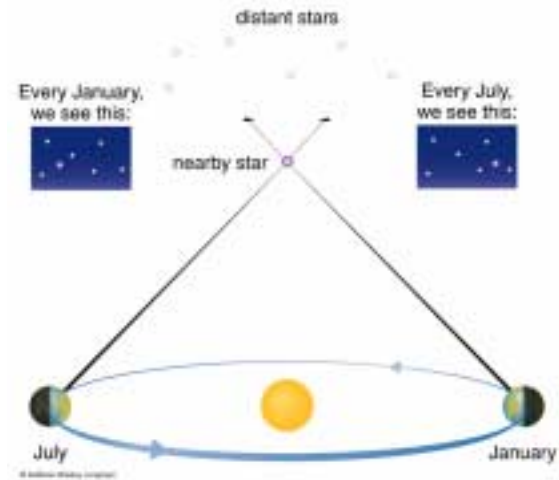
2. Seasons (Tilt of the Earth's axis).

- The Earth's seasons are entirely due to the tilt of the spin axis.
- Summer in the North (winter in the South) is when the North is tipped toward the sun.



3. Stellar parallax.

- The position of a nearby star can shift slightly after 1/2 a year due to parallax.
- One can determine the distance to a nearby star from the parallax angle.
- 1 Parsec (3.26 light-years) is the distance to a star with a parallax angle of 1 arcsecond.

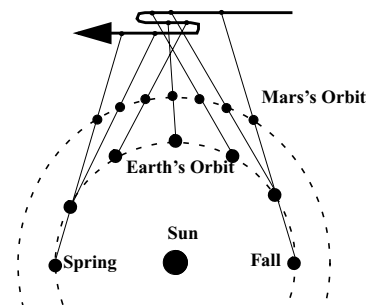


RELATIVE MOTION IV - PLANETARY ORBITS

1. Orbital Periods.

- Mercury orbits the Sun in about 3 months, or 0.24 years.
- Pluto orbits the sun every 284 years.
- Comets can have far longer periods.

2. Apparent Retrograde Motion

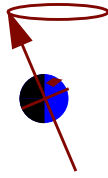


- The outer planets can appear to move backward (or westward) with respect to the stars when it is closest to Earth.
- Apparent Retrograde Motion is an historically important feature difficult to explain with a Geocentric universe.

RELATIVE MOTION V, VI, AND VII

1. The 26,000 Year Precession

- Polaris
- Vega



- In ~13,000 years, Vega will be the new “North Star”.
- The night sky has changed since the first recorded observations (over 2500 years ago).

2. Orbiting About the Milky Way

- The solar system is in a 230 million light-year orbit about the Milky Way galaxy.

3. The Expanding Universe.

- Galaxies are moving away from each other.

IV. HISTORY OF ASTRONOMY

1. The Egyptian Clock

- The beginning of the 24 hour clock:

2. The Metonic Cycle

- 235 months in 19 years.
- Years 3, 6, 8, 11, 14, 17, and 19 have 13 months. All other years have 12, giving 235 months in 19 years.

3. Greek Astronomy

- **Pythagorus** ~500 BC: His theorems allowed angles to be calculated more precisely.
- **Anaxagoras**: All planets and stars are flaming rocks; his thinking was influenced by observation of meteorites.
- **Aristarchus** ~350 BC: Raised the question, “could the sun be the center of the universe?”
- **Eratosthenes** ~350 BC: Estimated the size of the Earth with remarkable accuracy.
- **Hipparchus** ~150 BC: Devised the system of apparent magnitude. Cataloged ~850 stars.
- **Ptolemy** ~150 AD: Refined the concept of multiple circles to describe planetary motion.
- **Hypatia** ~415 AD: Directory of the Library of Alexandria and leading astronomer of her time. Murdered by anti-intellectual mob; the knowledge of the Greek astronomers was largely lost.

3. Modern Astronomy

- **Copernicus**: Asserted that the earth rotated on its axis once daily and traveled around the sun once yearly; a extravagant concept for his time.
- **Tycho Brahe**: Tycho Brahe made naked-eye observations with unparalleled accuracy.
- **Johannes Kepler**: Published three laws on planetary orbits. Brought forth the idea of ellipses.
- **Galileo Galilei**: He was the first to see Jupiter’s satellites, objects which did not orbit the earth directly. These findings were the death knell for the geocentric model of the universe.
- **Sir Isaac Newton**: Put forth the theory of universal gravitation and formulated calculus to mathematically describe universal laws of motion.

V. PHYSICS

1. Energy and Power

$$Power = \frac{Energy}{Time}$$

- **Energy** is defined as the ability to do work.
- **Power** is the rate of energy use, e. g. the amount of energy used in a period of time.

2. Units

- 1 calorie is the amount of energy it takes to raise one gram of water by 1°C.
- 1 **joule** (~1/4 of a calorie) is the standard MKS unit favored by science.
- 1 **Watt** is a joule/s.

3. Types of Energy:

- **Kinetic Energy** is the energy from motion.
- **Potential Energy** is stored energy that can be converted (gravitational, chemical, electrical).
- **Radiative Energy** is energy carried by light.
- **Thermal Energy** is a type kinetic energy called heat.

4. Heat Versus Temperature:

- **Temperature** is the measure of the average kinetic energy of a particle within a object.
- Thermal Energy, or heat, is the total kinetic energy in an object.

5. Mass is Energy:

$$E = mc^2$$

- Matter contains a tremendous amount of energy.
- This matter to energy conversion can explain the energy output of the sun and other stars.
- Converting matter to energy on Earth in a controlled fashion, however, is very difficult.

6. Basic Physics: States of Matter

- **Solid**: At low enough temperature (below 0 °C for water), individual molecules have very little kinetic energy. They can thus bond tightly to their neighbors to form a solid.
- **Liquid**: As the kinetic energy of the molecules increases (they move faster), they can break the bonds to the nearest neighbor, yet still remain tightly packed (incompressible).
- **Gas**: At even higher temperatures (above 100 °C for water), the molecules no longer stay together (evaporation). All bonding between molecules is gone.
- **Plasma**: At extremely high temperatures (greater than ~5000 °C), the molecules dissociate and ionize. The material is now freely moving electrons and ions.

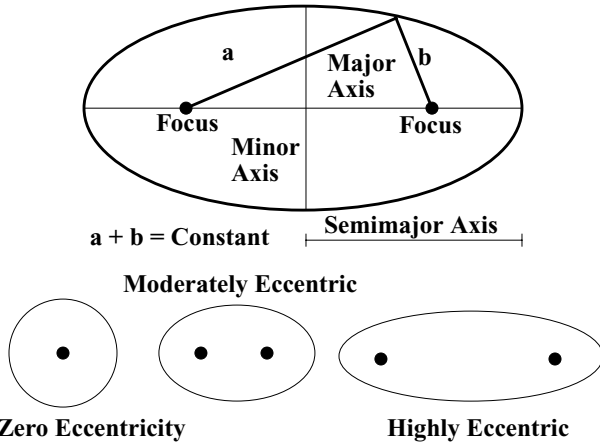
VI. KEPLER'S LAWS

1. The laws

- Planets travel in an ellipse with the sun at one of the foci.
- The planet sweeps out equal area in equal time. (The planet goes faster when nearer the sun).
- (3rd LAW ONLY VALID FOR BODIES ORBITING THE SUN!)

$$[\text{Orbital Period (years)}]^2 = [\text{Average Distance (AU)}]^3$$

2. Ellipses



VII. NEWTON'S LAWS OF MOTION

- An object at rest tends to stay at rest; an object in motion tends to stay in motion.
- Force = Mass x Acceleration.
- For any action, there is an equal and opposite reaction.
- Velocity is speed and direction.
- Acceleration is the rate of change of velocity.

$$a = \frac{d_2 - d_1}{t_2 - t_1}$$

- Mass is a measure of matter. Be careful not to confuse mass and force.

VIII. UNIVERSAL LAW OF GRAVITY.

- Every mass attracts every other mass through a force called gravity. (Planetary Perturbations)
- The force between any two objects is proportional to the product of their masses. (Bigger objects dominate)
- The force of gravity decreases with the square of the distance between the centers of the two objects. (Tides).

$$F = G \frac{M_1 M_2}{d^2}$$

- $G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg}\cdot\text{s}^2$
- Gravitational acceleration:

$$g = G \frac{M_{\text{Planet}}}{R_{\text{Planet}}^2}$$

IX. Newton's Form Of Kepler's 3rd Law

- This law applies to a planet orbiting the sun or a moon orbiting a planet.

$$p^2 = \frac{4\pi^2}{GM_{\text{Big}}} a^3$$

- Newtons form can be used to determine the mass of a planet if we know the orbital period of a moon and the distance for the moon to the planet,
- Another form:

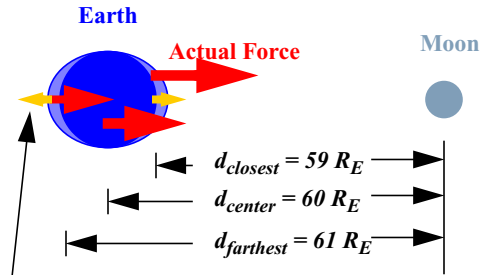
$$p^2 \propto a^3$$

- Escape velocity. An object, regardless of its mass, requires a minimum velocity to escape the gravitational attraction of another object:

$$v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

X. TIDES

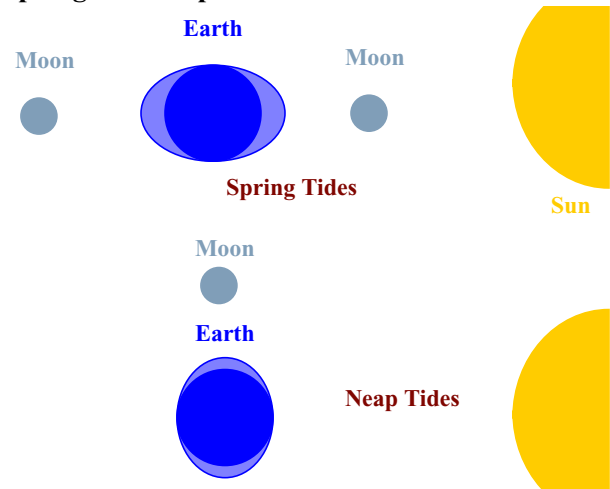
1. The tidal bulge.



Apparent (or leftover) Force

- The tidal bulge arises because the gravity of the Moon falls as distance square.
- The gravitational pull from the Moon is stronger than average on Earth's side facing the moon causing it to bulge toward the Moon.
- The gravitational pull from the Moon is weaker than average on opposite side causing it to bulge away from the Moon.

2. Spring and Neap Tides



- Spring tides occur if the Sun, Earth, and Moon line up, causing larger than normal tides.
- Neap tides occur if the Moon, Earth, and Sun form a right angle, causing lower than normal tides.