Solar system

- Definition of a Planet
- Order and Number of Planets
- Terrestrial Planets
  - Closest to Sun
  - Small Mass, Radius
  - Dense, rocky
  - Heavy molecules in atmospheres
- Jovian Planets
  - Furthest
  - Large Mass, Radius
  - Gaseous, low density
  - Hydrogen, helium in atmosphere (+ methane, ammonia, water)
- Formation of solar system
  - Current Characteristics that provide clues to process of formation
    - Mass mainly in the Sun
    - Planets in ecliptic
    - Orbits, rotations in same direction (generally)
    - Satellites orbit, rotate in the same direction (generally)
    - Density decreases with distance from Sun
    - Extensive craters
  - Solar nebula
    - Chemical composition
    - Rotation
    - Temperature effect on composition
    - Observations of disks around other stars
  - Formation of Planetismals - Condensation, accretion, collisions
  - Differentiation of planets – radioactive decay
  - Heavy Bombardment Era
  - Radioactive elements
    - Ages of solar system 1/2 life
    - Supernova in the past
- Other solar system
  - Method of detection
  - Surveys – Kepler mission
  - General characteristics of other systems
  - Habitable Zone

Earth

- Interior studies –
  - Earthquakes
    - P-waves
    - S-waves
    - Focus
    - Epicenter
    - Shadow zones
  - Internal structure

- Solid nickel-iron core
- Liquid nickel-iron core
  - Magnetic Field – required conditions
  - Magnetosphere
  - Van Allen Belts
  - Aurora
- Mantle
  - Lithosphere

Crust - types
- Oceanic
- Continental

Asthenosphere
- convection
- plate tectonics
- sea floor spreading,
- subduction,

Volcanoes - types
- Basaltic
- Composite – Andesitic Volcanoes
- Hot spot volcanoes

Atmosphere
- Composition
- Primary Atmosphere
- Secondary Atmosphere
- Influences on Atmosphere composition
  - Volcanic gases
  - Formation of Oceans
  - Sedimentation
  - Biological processes
- Greenhouse effect

Young vs Old planetary surface

The Moon

Surface features
- No atmosphere
- Craters
- Mare
- Highlands
- Mountains
- Volcanic features – volcanoes, rilles
- Faults – grabens, scarps

Internal Structure
- Magnetic features – possible iron core

Near side vs Far side
- Crust thickness

Tidal influences on Moon, Earth

Apollo exploration of the Moon

- Regolith
- Basalt
- Anorthosites,
- Breccia
- Search for water – LCROSS, Lunar Prospector, etc.

Origin of the Moon
- Impact Theory
- Support for Theory

Time line for Moon
- Formation after the Earth
- Heavy Bombardment
- Formation of Mare
- Human exploration

Mercury

Orbital period - Rotation Period relation
- 2 orbits = 3 rotations
- Orbital Precession – General Relativity

Exploration
- *Mariner 10*
- *MESSENGER*

Surface characteristics
- No atmosphere
- Craters,
- Plains
- Caloris Basin
- Jumbled/weird terrain
- scarps

Internal structure

Venus

Slow retrograde rotation

General physical characteristics similar to the Earth
- Mass, Radius, Composition

Atmosphere
- Composition
- Clouds – sulfuric acid
- Pressure
- Temperature
  - Greenhouse effect
- Influences on atmosphere

Exploration
- *Venera* Program
- *Pioneer, Magellan* – radar mapping
- *Venus Express* – atmosphere study

Surface types
- Lowlands
- Rolling Plains

- Continents
  - Aphrodite Terra – volcanos, large
  - Ishtar Terra - mountains, Maxwell Montes
- Volcanic features
  - Volcanoes
  - Flow features
  - Arachnoids
  - Coronae
  - Pancakes

Mars

- Features visible from Earth
  - Tilt of axis, length of day - like Earth
  - Ice caps
  - Atmosphere
  - Variation of surface features over time
- Mars mistakes –
  - Giovanni Schiparelli – canals
  - Percival Lowell's observations
- Exploration
  - *Viking 1, 2* – first successful landers
  - *Pathfinder* – first rover
  - *Mars Global Surveyor(MGS)*
  - *2001 Mars Odyssey*
  - *Mars Express*
  - *Spirit & Opportunity*
  - *Phoenix*
- Ellipticity of Orbit
  - Seasonal variations
  - Dust storms
- Atmosphere
  - Composition
  - Pressure
  - Temperatures
- Internal Structure
  - Rocky
  - Poorly defined magnetic field
- Surface Features
  - Craters – mainly in the south
  - Impact basins
  - Dry river channels – visible in the north
  - Volcanoes – mainly in the north
  - Rifts – Valles Marinaris
  - Faults
  - Ice caps – CO_2, H_20
  - Ice flow features
  - Desert dunes - sand

- Tharsis Bulge
  - Olympus Mons and other volcanoes
- Northern vs Southern Hemisphere features

Mars in the past
- Thicker atmosphere
- Water on the surface
- Grey hematite

Satellites of Mars –
- Asaph Hall
- Phobos, Deimos - characteristics

Jupiter

Largest Mass, Radius,

Composition – like the Sun

Exploration
- *Pioneer 10, 11*
- *Voyager 1, 2,*
- *Galileo* – orbiter and probe

Visible Cloud layers
- Haze
- Ammonia
- Ammonium Hydrosulfide
- Water

Results from the *Galileo* probe
- Hotter, denser
- High speed winds
- Chemically like Sun, minor differences

Differential Rotation

Great Red Spot

Other spots

Lightning, Aurorae

Internal Structure
- Core
- Liquid Metallic Hydrogen
- Liquid Hydrogen
- Visible cloud layers

Internal Heat source

Magnetic Field – source, strength

Ring

Galilean Satellites –
- Io
  - Innermost
  - Tidal heating
  - Volcanoes
  - Sulfur
  - Rocky
- Europa,

- Icy
- Water under ice
- Less tidal heating
- Ganymede
  - Largest satellite of all
  - Ice flow features
  - More craters
- Callisto
  - Outermost
  - Craters
  - Icy

Saturn

- Smaller version of Jupiter
  - Similar internal structure, composition, cloud layers
  - Less mass – lowest density
  - Less distinct cloud feature, storms
  - Weaker magnetic field, aurorae
- Rings
  - Visible from the Earth
    - A, B, C rings
    - Cassini & Encke divisions
    - Tilted
    - Other rings
    - Shepherd satellites
  - Origin
    - Roche limit
    - Icy composition
- Exploration
  - *Pioneer 11, Voyager I, 2*
  - *Cassini* – current mission
- Satellites – general characteristics
  - Titan
    - Largest of Saturn's
    - Atmosphere
    - Results from *Cassini- Huygens* probe
    - Surface features
  - Enceladus
    - Geysers
    - Link to rings

Uranus

- Discovery by Herschel
- Tilt of system – planet, satellite orbits, rings
- Rings - discovery
- Exploration – *Voyager 2*
- Cloud features
  - Spots

- Color of clouds - Methane
- Internal Structure
  - Rock
  - Water, Methan, Ammonia “ocean”
  - Liquid H, He
  - Visible cloud layers
- Magnetic field
  - Characteristics – off-axis, off-center
  - Source
- Satellites – general characteristics
  - Miranda
    - Discoloration
    - Grooves
    - Cliffs
    - Cause?

Neptune

- Discovery by Adams, Le Verrier (observed by Galle)
- Exploration – *Voyager 2*
- Similarities to Uranus
  - Similar size, radius, internal structure, composition
- Cloud features
  - Great Dark Spot
- Rings - ring arcs
- Magnetic field
  - off-axis and off-center
- Satellites – general characteristics
  - Triton
    - surface features
    - ice geysers

Pluto

- Discovery by Tombaugh
- Satellites: Charon and others
  - Tidally locked system
- Tilted system
- Likely Composition
- Atmosphere – nitrogen, methane, seasonal

Kuiper Belt Objects

- Trans-Neptunian Objects
- Eris
- Sedna
- Dwarf planets
- Plutoids

Comets

- Characteristics – Dirty Snowball
  - Ice – water, methane, ammonia, carbon dioxide
  - Dirt – carbon

- Structure
  - Nucleus – core
  - Coma or Head
  - Tails
    - Gas/Ion
    - Dust
  - Evaporation over time
- Source of comets
  - Oort Cloud - long period comets
  - Kuiper Belt - short period comets
  - Other Objects
    - Quaoar – large Kuiper Belt object
    - Sedna(?) – inner Oort cloud?
    - Pluto – planet or Kuiper Belt object?
- Famous comets
  - Halleys
  - Hale-Bopp
  - McNaught
- Comet exploration
  - *Giotto* – Halley's Comet
  - *Deep Impact* – Tempel 1, Hartley 2
  - *Stardust* – Wild 2, Tempel 1

Asteroids (Minor Planets)

- Locations
  - Asteroid Belt
  - Trojan Asteroids
  - Near Earth Asteroids (NEA)
  - Potentially Hazardous Asteroids (PHA)
- Exploration
  - *Galileo* images
  - *NEAR* spacecraft
- Ceres – largest asteroid
- Gaspra, Ida – observed by *Galileo*
- Vesta – *Dawn* spacecraft
- Kirkwood gaps – influence of Jupiter
- Types
  - S-types
    - Near Mars
    - Silicates (silicon) rich
  - C-types
    - Further out
    - Carbon rich
    - Most common
  - M-types
    - Metal
    - Least common

Meteors, Meteoroids, Meteorites

- Difference of terms
- Meteor Showers
  - Cause
  - Major Showers
    - Geminids
    - Leonids
    - Perseids
- Meteorites
  - Stony -Most common
    - Silicon, Carbon
    - Carbonaceous chondrites – water, amino acids
  - Stony-Irons -rarest
  - Iron
    - Iron-nickel mix
    - Widmanstatten Figures
  - Martian Meteorites
  - Micro-meteorites

Impacts

- Tunguska
  - Characteristics
- Manson Iowa
- Craters on the Earth
- Impact on Jupiter
  - Shoemaker-Levy 9
  - Later impacts observed
- Future impacts?