PHY 241 Planetary Systems - Final Exam Revision

Exam Date & Time: TBD

Terms and Definitions

- Orbits
  - Semi-major axis
  - eccentricity
  - inclination
  - true anomaly
  - pericenter - definition, orientation of $\mathbf{x}$ and $\mathbf{v}$
  distance in terms of orbital elements $q = a(1 - e)$
  - apocenter - definition, orientation of $\mathbf{x}$ and $\mathbf{v}$
  orbital elements $q = a(1 + e)$
- Kepler's 3 Laws: be able to derive for circular orbit.
- Hill Radius - what does this tell you
- Roche Radius - what does this tell you
- Escape Velocity
- Circular Orbital Velocity
- Tidal quality factor Q -qualitatively
- Love Number (k_{2p} -qualitatively)
- RMS velocity of ideal gas
- Criteria for atmospheric retention

Populations

- Terrestrial Planets (i.e. Mercury, Venus, Earth, Mars) orbital semi-major axes
- Giant planets (Jupiter, Saturn, Uranus and Neptune) orbital semi-major axes
- Regular satellites - (rough sizes, types of orbits, a,e,i) Given an example or two, Where do their orbit in R_p, r_H?
- Irregular satellites (rough sizes, types of orbits, a, e, i) Where do their orbit in R_p, r_H?
- Planetary Rings - where do they exist (orbital properties in terms of R and r_H)? Why do they exist (i.e. what prevents them from accumulating into larger satellites?
- Extrasolar planets
  - describe detection methods and limitations (what is measured and how are planetary properties inferred?) - what are their physical and orbital properties? - Could 'hot jupiters' (i.e. gas giant planets with short, $\sim$10-day orbital periods) form in their current orbits? Offer evidence and arguments that support or refute your case. (temperature and core accretion? condensation of material near the star?).

Physical & Mathematical Definitions

- \- Centripetal Force
  \- Gravitational Force
  \- Gravitational potenitial energy
  \- Kinetic energy
  \- Total energy
  \- Angular momentum
  \- Torque
  \- Total system angular momentum.

  \- Roche Radius
  \- Hill radius
  \- Escape Velocity
  \- Height of equilibrium tide
  \- Angular momentum - rotational, orbital
  \- Moment of Inertia - definition in general also for a sphere
  \- Volume of a sphere

  \- Luminosity
  \- Flux
  \- Albedo
  \- subsolar temperature
  \- blackbody equilibrium temperature
  \- Pressure
  \- Hydrostatic equilibrium

  \- Stefan-Boltzman Law (or just Stefan's Law)
  \- Blackbody Radiation Spectrum
  \- Wien's Law
  \- Habitable Zone (calculating boundaries)
  \- Snow/Ice Line (relevance for origin of Earth's water)

Derivations to know how to do:

- Synchronous orbital radius
- Using energy relation derive:
  - circular orbital velocity
  - escape velocity
  - vis-viva equation
- Derive expression for angular momentum of an elliptical orbit using:
  \- definition of orbital angular momentum
  \- distance to pericenter or apocenter
- Derivation of Hill radius/ Roche radius
- Semi-major axis of synchronous orbit.

- Maximum rotational angular velocity (or minimum rotation period).
- Using tidal torque formula and orbital angular momentum for a circular orbit derive an expression for semi-major axis as a function of time.
- Derive expressions for subsolar, equilibrium temperature
- Gravitational binding energy of a uniform sphere

Types of problems we've done:

Go over courseworks and solutions for details. Good example problems can also be found in the texts: Moons and Planets (Hartmann), Introduction to Astronomy and Astrophysics, Zeilik and Smith (various editions in the library) and Physical Processes in the Solar System (Landstreet).

Here is a sample listing of the types of problems.

- Using maximum elongation angle to determine size of orbit of inner planets (vulcanoids from cw#1)
- Calculating scales and characteristic quantities
  - orbital velocities
  - Hill radii
  - escape velocity
  - orbital angular momenta
  - rotational angular momenta

- Determining the size of an orbit, from an observed speed and position (vis-viva equation).
  - fireballs
- Transfer orbits.
  - calculating change in speed needed to go from one orbit to another. (many variations on coursework)
- Tides:
  Calculating Tidal height of equilibrium tide
  Calculating tidal evolution using relation between a_1,a_0,t_1,t_0 and k_2/Q. Many variation on coursework, but usually fall into classes of problems. For example:
  - Given k/Q, how long does it take to go from (a_0, t_0) to a_1? - given da/dt what is k/Q - given da/dt what is $d\Omega/dt$?
- Radiation, Albedo and surface temperature problems
  - Determine size of object from measuring albedo at two different wavelengths. - Determine surface temperature from stellar luminosity, albedo and heliocentric orbital radius.
- Atmospheric Retention
  - Determine which moleculare constituents can be retained from surface temperature and molecular species. E.g. Can Earth retain a molecular hydrogen atmosphere? Why or why not?
- Planetary structure
  - Use hydrostatic equilibrium condition to determine central pressure of a uniform self-gravitating sphere. - Use hydrostatic equilibrium condition to determine pressure profile inside a uniform sphere. - Use pressure profile and material strength to estimate height of irregularly shaped surface features on a body (e.g. the height of mountains and valleys).

- Gravitational Binding Energy
  - Given planetary physical characteristics, how much energy is released in assembling a body?
  - What is the resulting rise in temperature due to the release of this energy (e.g. using specific and/or latent heats)?

Explanations & physical interpretations:

- Explain relation between Roche radius and location of planetary rings
- Explain what causes tidal deformation
- Explain why there are two high tides and two low tides everyday. How tides in Earth from the Moon and Sun affect evolution of the system.
- Explain how a body's physical strength might affect the amplitude of the tide raised.
- Using a diagram of the tidal bulges raised and a force diagram, explain why a satellite outside synchronous
  - experiences a net torque and evolves outward.
  - what are possible fates of satellite/planet for this evolution?

- Using a diagram of the tidal bulges raised and a force diagram, explain why a satellite inside synchronous
  - experiences a net torque and evolves inward.
  - what are possible end fates for such satellites?
- What are the consequences of tides and friction for
  - orbits
  - rotation states
  - heating
  - when is the primary heated? - when is the secondary heated?
- Friction and Diurnal (satellite tide)
  - explain how eccentric orbit of secondary leads to dissipation in secondary and damping of the eccentricity.
  - Some important consequences of this evolution?

Equations to just know

Suggested references for revision:

- Your notes.
- Slides from website (mostly graphical)
- Moons & Planets (mostly textual descriptions, some example problems)
- scans from IAA for Roche radius derivation (see website for some scans and the library for additional copies of the text)
- go over coursework/solutions, derivations from class notes/text

- Ch. 1 Introductory Astronomy & Astrophysics (hereafter IAA), by Zeilik, Gregory and Smith (several copies in the Library) - see scans on website.
- Ch. 2 & 3 Moons & Planets, Hartmann (hereafter, just Hartmann).