Astrophysics. Exam I Review

Chapter 1

- Ancient civilizations and their understanding
- Ancient Greek astronomers
- Stellar parallax
- Precession (what is it, period, consequences)
- Celestial Sphere
- Coordinates systems
- Planetary configurations (opposition, etc)
- Synodic and sidereal periods; $1/S = 1/P_{in} - 1/P_{out}$
- Proper motion ($\mu = v_\theta/r$), radial motion (v_r)

Chapter 2

- Ptolemaic system (epicycle, deferent, etc)
- Heliocentric system
- Copernicus, Tycho, Kepler, Galileo, Newton
- Ellipses ($r = \frac{a(\epsilon^2-1)}{1+\epsilon\cos\theta}$)
- Kepler's Laws
- Newton's Laws
- Law of Universal Gravitation
- Shell theorems
- Coordinate conventions for 2-body problem . (Relative orbit or C.O.M,absolute coords)
- Reduced mass: $\mu = \frac{m_1 m_2}{m_1+m_2}$

- Center of mass (COM) coords: $\vec{r}_1 = -\frac{\mu}{m_1}\vec{r}$; and $\vec{r}_2 = \frac{\mu}{m_2}\vec{r}$
- Center of mass (COM) coords: $\vec{r} = \vec{r}_2 - \vec{r}_1$
- Total energy in terms of reduced mass:

$$E_{tot} = \frac{1}{2}\mu v^2 - G\frac{M\mu}{r}$$

- Total orbital angular momentum

$$\vec{L}_{tot} = \mu\vec{r} \times \vec{v}$$

- Results from the derivation of Kepler's 2nd law
  1. $\frac{d\vec{L}}{dt} = 0$ (angular momentum is constant in 2-body problem)
  2. $\frac{dA}{dt} = \frac{L}{2\mu}$
  3. $L = \mu\sqrt{GMa(1-e^2)}$
- The total energy of a 2-body system is 1/2 of the time-average potential energy: $E_{tot} = \frac{1}{2}\langle U\rangle$
- Escape velocity: $v_{esc} = \sqrt{2Gm/r}$
- Kepler's 3rd law (modified)

$$P^2 = \frac{4\pi^2}{G(m_1+m_2)}a^3$$

- Virial Theorem: for a multi-body system in equilibrium, the time-averaged kinetic energy and potential energy are related by:

$$-2\langle K\rangle = \langle U\rangle$$

- Also, for both multi-body systems and 2-body systems, total energy is:

$$\langle E\rangle = \frac{1}{2}\langle U\rangle$$

Chapter 3

- Parallax and distance. $d(pc) = \frac{1}{p''}$ (for baseline = 1 AU)

- Parallax (more general): $d = \frac{B}{2\tan p}$
- Flux, $F = \frac{L}{4\pi r^2}$ in Wm^{-2}
- Luminosity: total energy leaving an object in all directions over all wavelengths
- Monochromatic luminosity: $L_\lambda d\lambda$ = a luminosity only within the wavelength range λ to $\lambda + d\lambda$.
- Luminosity (blackbody) = $L = A\sigma T^4$.
- Luminosity (not quite perfect blackbody) = $L = \epsilon A\sigma T^4$.
- Magnitude System
  - 5 magnitudes difference correspondes to a flux ratio of 100X.
  - smaller numbers means brighter
  - apparent magnitude: $m = -2.5log_{10}\frac{F}{F_{ref}}$
  - absolute magnitude, M: the apparent magnitude of a star at the standard reference distance (10 pc = 32.6 ly).
  - absolute magnitude, $M = -2.5log_{10}\frac{L}{L_{ref}}$ (L_{ref} is about $80 \times L_\odot$.)
  - absolute magnitude is a measure of luminosity, apparent is a measure of brightness.
  - Example: $M_\odot = 4.76$, $m_\odot = -26.7$, $L_\odot = 3.826 \times 10^{26} W$
  - Distance modulus, (m-M),: $(m - M) = 5log_{10}\frac{d}{10pc}$
  - Distance modulus: an alternative measure of distance that directly tells you how the brightness of the object differs from its brightness at 10 pc.
- Wave nature of light
  - Light has wave properties: interference pattern formed by double-slit
  - $c = \lambda\nu$
  - Time-averaged Poynting Vector: a measure of monochromatic flux
  - Time-averaged Poynting Vector: $\langle S \rangle = \frac{1}{2\mu_0}E_0B_0$ (mks) or $\frac{c}{8\pi}E_0B_0$ (cgs)
  - Radiation pressure is greater when light is completely reflected than when light is absorbed - transfer of momentum.
  - Radiatio pressure, absorption: $F_{rad} = \frac{SA}{c}\cos\theta$
  - Radiatio pressure, reflection: $F_{rad} = \frac{2SA}{c}\cos^2\theta$

- Blackbody radiation
  - Blackbody: an ideal emitter and absorber.
  - Blackbody absorption: 100%
  - Blackbody emission: spectrum obeys Planck function, Wien's Law, and the Stefan-Boltmann Law.
  - Wien's Law: $\lambda_{max}T = 0.0029mK = 2.9 \times 10^7 \mathring{A}K = (5000\mathring{A})(5800K)$
  - Stefan-Boltzmann law: $F_{surf} = \sigma T^4$
  - Planck's Law: $B_\lambda(T) = \frac{2hc^2/\lambda^5}{e^{hc/\lambda kT}-1}$
  - Color indices: $B - V = m_B - m_V = -2.5\log(\frac{\int F_\lambda S_B d\lambda}{\int F_\lambda S_V d\lambda}) + C_{B-V}$

Chapter 4

- Special relativity: the physics of high speeds
- $z = \Delta\lambda/\lambda$
- $z = \frac{v_r}{c}$ for low v_r
- $z = \sqrt{\frac{1+v_r/c}{1-v_r/c}} - 1$ for high v_r

Chapter 5

- History of spectroscopy
- Kirchoff's Laws: how absorption, emission and continuous spectra are formed.
- Space motion of a star: $v = \sqrt{v_r^2 + v_\theta^2}$
- $E_{photon} = h\nu = hc/\lambda = pc$
- Photoelectric Effect: $K_{max} = h\nu - \phi$
- Compton Scattering: $\lambda_f - \lambda_i = \frac{h}{m_e c}(1 - \cos\theta)$
- Bohr model of hydrogen atom - required $L = n\hbar$
  - Energy levels are labeled n=1 (ground), 2, 3, 4, etc.
  - $r_n = a_0 n^2$
  - $E_n = -13.6eVn^{-2}$
  - An upward transition means atom has absorbed energy
  - A downward transition means the atom emits a photon