Some suggestions for studying ...

- Make your own course outline
  Today’s class just hits the high points
- Be familiar with the textbook
- Review the homework problems
- Work problems from other sources
  ↪ Do last year’s exams
  ↪ Check out other web sites

... and for taking the final

- Do the questions you know first
- Try not to “look up” answers
  ↪ Trust what you know
- Use “look up” for hardest questions
- Remember: Grades will be curved
  ↪ Don’t panic!
Basic Physics
Gravitation and Motion

• Newtonian Gravity

Force: \[ F = \frac{GM(r)m}{r^2} \]

Potential Energy: \[ U = -\frac{GM(r)m}{r} \]

• Circular Motion

\[ F = ma \text{ where } a = \frac{v^2}{r} \]

• Applications

Energy release in gravitational contraction
Center of mass and motion of binary systems
   Examples: Cygnus X-1, Galaxy & M31
Mass at the center of M87
Escape velocity
   Schwartzschild radius
Newtonian cosmology
Basic Physics

Electromagnetic Radiation

• Regions of the electromagnetic spectrum
• Diffraction
• Doppler shift
  Nonrelativistic and relativistic

Primary sources of electromagnetic radiation

• Line sources: Atomic & Molecular states
  Bohr atom, Balmer formula
• Blackbody radiation: Thermal, continuous
  Stefan-Boltzmann law ⇒ $L = 4\pi R^2 \sigma T^4$
  Wien’s Displacement Law ⇒ “Color”

Remember: Thermal energy $E \approx kT$ per particle

• Synchrotron radiation: Nonthermal, continuous
  Spectrum falls like $1/\nu$
The Solar System
A model for much of the basic physics

• **Mass of the Sun and planets**
  Circular orbit approximation works well

• **Kepler’s Laws**
  Elliptical orbits
  Properties of ellipses
  Equal areas in equal times
  Conservation of angular momentum
  \[ P^2 \propto a^3 \]
  Natural units: Years, AU, Solar mass

• **The Roche Limit**
  Tidal disruption and the rings of Saturn

• **Solar system details**
  Atmospheres
  Moons and rings
  Asteroids and comets
Telescopes

• Different telescopes for different wavelengths

• “Images” or “data”

• Diffraction limit of resolution
  
  Telescope with aperture \(d\) observing at a wavelength \(\lambda\), \(\theta = 1.22 \times \frac{\lambda}{d}\) with \(\theta\) in radians

• Measures of angle
  
  \[360^\circ = 2\pi \text{ radians}\]
  \[57.3^\circ = 1 \text{ radian}\]
  \[1^\circ = 60 \text{ arcmin (')}\]
  \[1' = 60 \text{ arcsec (")}\]

Example: For \(\theta\) in arcsec, write

\[
\theta = \frac{360}{2\pi} \times 60 \times 60 \times \frac{\lambda}{d} = 206265 \times \frac{\lambda}{d}
\]
Measuring Stars

Distances and magnitudes

• **Parallax:** 1 parsec (pc) = 1 a.u./sin(1”)

• **Magnitude:** Measure of brightness
  - Apparent (m,V,...) or absolute (M,M$_V$,...)
  - Inverse log scale: $m \propto \log \frac{1}{L/d^2}$
  - Color Index
  - Distance modulus $m - M = 5\log d - 5$
  - Bolometric magnitude

**Binary systems**

• Not unusual!

• Important for determining properties
  Combine physics with observations
  $\Rightarrow$ Mass and radius determined

Example: $L \propto M^3$ (approximately)

*This is for main sequence stars only!*
Stellar Properties & Evolution

• Spectral class and surface temperature

• Luminosity class and “size”

• HR Diagrams
  ☞ Historical, Observational, or Physical
  ☞ Main sequence, giants, dwarfs

• Properties of Main Sequence
  ☞ Mass and luminosity \( \Rightarrow \) Lifetime
  ☞ Mass and radius

• Stellar structure
  ☞ Hydrostatic Equilib. \( \Rightarrow \) Central pressure
  ☞ Equation of state \( \Rightarrow \) Central temperature
  ☞ Nuclear reactions

• Evolutionary paths
  ☞ Study on HR diagrams
  ☞ Solar mass stars \( \text{vs} \) massive stars
  ☞ Population II stars
Special Case Stars
Small, Variable, Violent, or just plain Weird

• Small (i.e. “compact”) stars
  ☞ White dwarfs
  ☞ Neutron stars
  ☞ Black holes

• Variable stars
  ☞ Cepheids (Type I and II) and RR Lyrae
    Distance indicators!

• Violent stars
  ☞ Novae
  ☞ Type I Supernovae
  ☞ Type II Supernovae

• Weird stars
  ☞ Close binaries with compact object
    Cygnus X-1 (black hole companion)
    Centaurus X-3 (neutron star companion)
    SS 433: Weird jets!
The Interstellar Medium

Composition

• Dust and gas

• Dust scatters light
  ☞ Dense areas (“clouds”) are dark
  ☞ General areas are “reddened”
    ⇒ Modify distance modulus!

• Gas absorbs or emits “light”
  ☞ Hot gas emits in optical (“HII regions”)
  ☞ Cold gas emits in radio (“HI regions”)

Star formation

• Collapsing clouds of gas and dust
  ☞ Time scale for collapse
  ☞ Mass scale for collapse

• Disks and planet formation
The Universe

• Hubble’s Law
 ☞ Optical spectra of galaxies
    Emission and absorption lines vary
    Ca H and K lines generally visible
 ☞ For “nearby” galaxies: \( z = \frac{H}{c} d \)
    ⇒ Interpret as “Doppler shift”
 ☞ Implies the universe is expanding
    ⇒ The age of the universe
 ☞ Find \( H_{\text{TODAY}} = H_0 \approx 75 \text{ (km/sec)/Mpc} \)

Consistent with the age of globular clusters?

• Large scale structure
 ☞ Clusters of galaxies
    The local group
    The Virgo cluster
    The Coma cluster
Active Galaxies and Quasars

Galaxies with very bright central regions

• Radio galaxies
  ➕ Ellipticals
  ➕ Compact (M87) or extended (Cygnus A)
  ➕ Suspect supermassive black holes
    Accretion disk ⇒ jets
  ➕ The core of M87

• Seyfert galaxies
  ➕ Spirals with very bright centers
  ➕ Strong emission lines

• Quasars
  ➕ Old days: Starlike radio sources
  ➕ Very large redshifts
  ➕ Today: Very distant active galaxies
Cosmology

• The Flat Universe
  ☞ Relation between $dR/dt$, $R$, and $M$
  ☞ Relation between $H$ and $\rho$
  $\Rightarrow$ The universe is probably flat

• Justification through General Relativity
  ☞ Energy gravitates: Light bending

• Cosmic Microwave Background
  ☞ Lots and lots of photons
  ☞ Photons are low energy (today)

• The Big Bang
  ☞ Photons ruled the early universe
  ☞ Particle creation in the primordial soup
  ☞ The first three minutes: H, He, ...

• Formation of the galaxies
  ☞ Looking back in time
  ☞ Protogalaxies with the HST