Review for Final

- elementary mechanics
  - Newtonian mechanics
  - gravitation
  - dynamics of systems of particles
- Lagrangian and Hamiltonian Dynamics
  - Lagrangian mechanics
  - Variational dynamics
  - Hamiltonian dynamics
  - (theoretical mechanics)
- oscillations
  - SHO incl. damped and forced
  - coupled SHOs/normal modes
  - continuous limit
- central forces and scattering
- Emphasis will be on applications, not derivations
- Use Appendix B of lecture notes as review guide

Format of Final

- Similar to midterm in format
  - take-home
  - open notes, problem sets, solns, H&F
  - no collaboration, no other textbooks, no web searches, no symbolic manipulation programs, no calculators needed
- 4 hours
- Exam-taking tips
  - Don’t fixate on a problem -- they are not equally difficult.
  - “See” your way through the physics of the problem before digging into the algebra. Don’t “grind” -- keep the physics in mind to guide you.
  - if you are running out of time, try to indicate what you would do to complete the problem.
- Typo corrections out next week hopefully...

Elementary Mechanics

- Will not be emphasized -- had lots of it on the midterm -- likely will have no more than 1 or 2 (short) problems
- Newtonian mechanics (Section 1.1)
  - Solving problems -- finding the forces and determining the EOM
  - Using work and energy to solve problems
- Gravitation (Section 1.2)
  - gravity as the perfect example of a conservative force, where a potential energy can be defined -- *defining* and using the potential energy
  - Newton's iron sphere theorem as an application of potential energy
- Dynamics of systems of particles (Section 1.3)
  - using separation between center of mass motion and internal dynamics to solve problems (e.g. rocket motion)
  - using conservation of momentum and energy for systems to solve problems (e.g., scattering)

Lagrangian Mechanics/Dynamics

- Foundations -- i.e., more than just the E-L eqn
  - What is a holonomic constraint?
  - Understand how to define problems in terms of coordinates that incorporate constraints
- Ph196-only topics
  - Nonholonomic constraints
  - Understand how calculate generalized forces (PS3 #5)
  - Remember the Generalized Eqn of Motion

$$\sum_i \vec{F}_i^{(nc)} \cdot \frac{\partial \vec{r}_i}{\partial q_k} = \mathcal{F}_k = \frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_k}\right) - \frac{\partial T}{\partial q_k}$$

- Applications -- using the E-L eqn
  - Calculating the kinetic and potential energies -- remember to begin in a coordinate system you understand, then rewrite in generalized coords
  - You will get most of the points in such problems for writing down E-L eqns properly, make sure you do at least that much. Remember the signs in the E-L eqn -- it is a “physics” sign, not an “algebra” sign.

Variational Dynamics

- Calculus of variations
  - again, more than just the E-L eqn, remember how to use the calculus of variations for generic minimization
- Lagrange multipliers
  - be comfortable with using them and determining constraint forces from them: *This is a topic a lot of students have problems with! It is subtle!*
- Ph196: Incorporating nonholonomic constraints

Hamiltonian Dynamics

- Noether's theorem
  - know how to check whether a transformation is a symmetry transformation of the Lagrangian
  - know how to calculate conserved quantities
- Hamilton's equations of motion
  - be sure to understand how to use them
  - remember the distinction between (q, dq/dt) and (q, p) as independent variables
  - Liouville's theorem -- applications are pretty straightforward, unlikely you will get a question dealing with how it is proven.
  - Virial theorem -- proof is not so important as being able to use it

Theoretical Mechanics (Mostly Ph196)

- Canonical Transformations
  - Be sure you understand which variables are independent in which cases:
    - generating function: pairs (q,Q), (q,P), (p,Q), (p,P) are independent
    - canonical transformation: (q,p) or (Q,P) are independent
  - How do you know a generating function is valid?
  - What is preserved under a canonical transformation? Why?
- Symplectic Notation and Poisson Brackets
  - Be able to use them -- it may simplify some problems
- Hamilton-Jacobi
  - Don't need to know the derivation
  - Understand how to use it to solve problems
- **Ph106:** Action-angle variables and adiabatic invariants
  - Notes are not very good on this topic because too much time spent on derivation (aimed at Ph196). Know how to use for problems. See PS5 #7 and PS6 #1. What does adiabatic invariance say is preserved in phase space?

Simple Harmonic Oscillator

- Basics
  - Understand how to determine stability and frequency of small oscillations
  - See, e.g., PS6 #3 and PS7 #5 for examples on how to expand about an equilibrium point.
- Damped SHO
  - Know the three cases
  - Understand how to use Green's functions to determine response to transient drive
- Driven SHO
  - Understand the distinction between transient and steady-state response
  - Understand the complex amplitude response plane -- magnitude and phase of response, physical meaning

Coupled SHO and Waves

- Know how to use the technology!
  - determining normal mode frequencies
  - finding normal mode vectors (including normalization)
  - applying initial conditions to find mode coefficients to get full time evolution (esp. understand intuitively how initial conditions excite different modes)
- Understand why degeneracy occurs, how to deal with it
- Understand the limiting process to go from loaded string to continuous string, and how it relates to normal modes

Central Forces

- Formalism
  - Know how to go from the 3D problem to the 1D problem and how to write the effective potential and effective 1D Lagrangian.
  - Understand the $1/r \rightarrow u$ transformation and how to *use* the $u(\theta)$ orbit and energy equations for more general cases -- e.g. PS7 #5 and the example precessing orbit solution given in PS7
- Kepler applications
  - Understand the Keplerian orbits, how geometry is related to energy and angular momentum
  - Using conservation of energy and angular momentum to understand how to go from one orbit to another -- lots of examples in previous years' problem sets, PS7 #3
- Scattering
  - how to go from (ℓ, E) to (b, v_∞)
  - getting $b(\theta_*)$ and differential cross section
  - CM $\leftrightarrow$ lab frame transformations (PS7 #6)

Study Tips

- Use Appendix B of the notes as a review guide -- you should feel comfortable with everything there.
- *Do problems!*
  - Certainly, you should understand the derivations as best you can...
  - but, ultimately, we can only really test your ability to apply what you've learned; it's hard to think up variants on the derivations.
  - Try redoing the examples from the lecture notes without the notes in front of you
  - Use the sample problems from previous years. Email me for solutions.
  - Go to the library and xerox problems out of Thornton, Symon, Goldstein, Fowles and Cassiday, etc.

Next Term

- Rotations, rotations, rotations
  - How to deal with rotating coordinate systems
  - Dynamics of rigid bodies (torque, precession, nutations, etc.)
  - Special relativity
    - Can be viewed as a generalization of rotation formalism
- A taste of classical field theory
  - How to generalize the action and E-L formalism to fields
  - Noether's theorem for fields
  - Scalar field, EM field, hopefully the relativistic electron
  - Local symmetry transformations and gauge invariance
  - (Spontaneous symmetry breaking?)