Physics 213a-2011 Coverage for Exam 1

Reading:
Chapter 1: all; Chapter 2: 2.1-2.3 only
Chapter 3: 3.1-3.4. (I expect you to know that we require $Q > \frac{1}{2}$ for underdamped behavior, but I don’t expect you to be familiar with the solutions for the critically-damped or overdamped cases.)

Class sessions: Start of semester through the first part of 9-19-11

Assignments: 1-3

Topics (topics in boldface are somewhat more important, but don’t ignore the others):
Second-order differential equations (e.g. SHO):
- General solution has two adjustable constants
- How to test a guess to determine if it’s a solution

Complex numbers:
- Euler’s equation
- Conversion between cartesian ($a + ib$) and polar ($Ae^{i\alpha}$) forms
  - Taking the Real part, including commutation relations with addition, taking derivatives, multiplying by real, multiplying by complex
  - Taking the Imaginary part
  - Representing in the complex plane
- Correspondence between multiplication by $e^{i\alpha}$ and rotation in the complex plane
- Representing phase relationships between complex numbers by drawing them as vectors in the complex plane

Solving motion problems:
- How to go from a knowledge of an object’s mass and the forces acting on it to writing down a DEQ which describes its motion
  - Being able to make reasonable guesses for solutions (in most cases, a guess of the form $x = Re(z)$, where $z = Ae^{i\beta} e^{i(\omega t + \phi)}$, where $A$, $\beta$, $\omega$, and $\phi$ are real and are to be determined, would be reasonable)
  - Determining the values of parameters (e.g. $\omega_0 = \sqrt{k/m}$) by substituting the guess into the DEQ
  - Determining the values of adjustable constants (e.g. $A$ and $\phi$) from initial conditions
  - Finding the phase and amplitude relationships between position, velocity, acceleration, and applied force

Simple (not damped or driven) harmonic oscillator:
- Hooke’s law
- Potential energy
  - why any stable system can be modeled as a harmonic oscillator
  - be able to quickly write down and understand expressions (in complex exponential format) for and sketch position, velocity, and acceleration
  - understanding the phase relationships between velocity, position, and acceleration; being able to represent these using vectors in the complex plane
  - extracting the actual motion from the complex exponential representation
  - awareness that frequency does not depend on amplitude
  - relations between and meaning of $\omega$, $T$, and $f$
    - be able to quickly derive expressions for kinetic energy and potential energy, understand how the energy is traded back and forth between these forms during the cycle
    - examples
      - elasticity & Young’s modulus, including the meaning of yield stress
      - pendulums
        - be qualitatively aware of how this deviates from SHM at large amplitudes
effective spring constant for a pendulum
LC oscillator (isomorphism with mass on spring)

Complex notation for AC circuits
Expressions for impedance of \( R, C, \) and \( L \)
Extracting the actual \( I \) and \( V \) from the complex versions
Complex version of Ohm’s law
Analysis of “voltage divider” circuits, e.g. low-pass filters, involving resistors, capacitors, & inductors

Damped harmonic oscillator:
DEQ of motion
definitions of and meaning of \( b, \gamma \) and \( Q \)
underdamped for \( Q > \frac{1}{2} \), critically damped for \( Q = \frac{1}{2} \), overdamped for \( Q < \frac{1}{2} \)
solution for underdamped case –
be able to quickly write down and understand expressions (in complex exponential format) for
and sketch position, velocity, and acceleration
dependence of average energy and amplitude on time
relation between \( \omega \) and \( \omega_0 \), awareness that they are nearly equal except for very heavy damping
damped electrical series RLC oscillator

Miscellaneous
Taylor series
Slipperiness of the arctan and how to deal with it

General:
Be ready for problems that show harmonic motion/behavior but are not just a mass on a spring.
Get in the habit of using the force equation or the energy equation to find the effective spring constant and effective mass, and using these quickly to find \( \omega_0 \). Similarly, get in the habit of picking out the effective value of \( b \) from the force equation, and using it, for example, to find the energy decay rate.

Be especially solid on all topics which appeared in starred boxes