Summary on unit 3 (update: 11/05/10)

Sec. 6.4-6.17. Pair-interactions and potential energy of multiparticles: \( E_{\text{sys}} = \sum_i (m_i c^2 + K_i) + \sum_{i<j} U_{ij} \).
Potential energy due interaction between one pair A and B:
- \( \Delta U = -W \), W is work done due to the force exerted by A on B, as B moves from initial to final.
- How is the force related to \( U \)? 1-variable cases: \( F_r = -dU(r)/dr \) and \( F_x = -dU(x)/dx \).
- \( U(r) \rightarrow 0 \) as \( r \rightarrow \infty \). \( |u(r)| \) increases, as \( r \rightarrow 0 \). Attractive \( U < 0 \), repulsive \( U > 0 \).
Gravity: \( U = -\frac{G m M}{r} \), \( F = -\frac{G m M}{r^2} \). Electricity: \( U(r) = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{r} \), \( F = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{r^2} \).
Satellite (circular orbit). Centripetal force: \( \gamma = \frac{mv}{r} \).
Photon spectra: \( \text{Boltzman factor (BF)}: \ E' = kT \exp(-\frac{E}{kT}) \).

Sec. 7.1-7.11. Energy in Macroscopic Systems
Ideal spring: \( U(x) = \frac{1}{2} k x^2 \), \( F_{\text{spring}} = -k x \). \( K + U = m v^2/2 = k A^2/2 \). \( x = A \cos \omega t \), \( \omega = \sqrt{k/m} \).
Morse potential: \( U_{\text{morse}} = E_M \left[ 1 - e^{-\alpha (r-r_0) \beta} \right]^2 - E_M \).
\( U(r) \) is a function of position coordinate only. It is independent of the paths how r is reached.
Energy principle: \( \Delta E_{\text{therm}} = Q + W \), \( E_{\text{therm}} = C m T \), where C is specific heat of m in units of J/g/K.
Dissipations: Terminal velocity at \( F_{\text{air}} = mg \). \( F_{\text{air}} = (-1/2)C \rho A v^2 \dot{v} \). Friction: \( F_{\text{static}} = \mu_s N \), \( F_{\text{kin}} = \mu N \).

Sec. 8.1-8.7. Energy Quantization and photons
When \( W_{\text{surr}} \) is negligible, the system is specified by its \( E' \)-state content, where \( E' = K + U \).
The \( E' \)-states in sun-comet (macro-) system compared to those in H-atom (micro-) system.
- Similarities. \( U(r) \propto -1/r \). For \( E' < 0 \), bound states. For \( E' \geq 0 \), continuum and unbound.
- Differences in \( E' < 0 \) region. Macro system can have bound states at any \( E' < 0 \), minimum \( r \) not well defined. Micro system has discrete bound states and has a ground state which defines \( r_{\text{min}} \).
Frank-Hertz experiment: \( e + Hg \rightarrow e + Hg^* \) It illustrates the discreteness of the 2nd level of Hg atom.

Photons: Light is made of wave-energy packets called photons (symbol \( \gamma \)). Size is \( \sim \lambda \) (wavelength).
\( E_\gamma = \hbar \omega = \hbar c / \lambda = 1240(eV nm)/\lambda \), with \( \hbar = h/2\pi \). The Planck constant \( h = 6.6 \times 10^{-34} J \) s.
- Atomic excitations: \( X + \text{atom} \rightarrow X + \text{atom}^* \). Energetic X may kick ground state e to an excited level.
- Emission: Decay from ith level leads to emission of \( \gamma \) with energy \( E_\gamma = E_i - E_j \), \( 1 < j < i - 1 \).
- Absorption: Electron at level excited to ith level leads to absorption (dark) line at \( E_\gamma = E_i - E_1 \).

Boltzman factor(BF): \( \exp(-E/kT) \). \( k = 1.38 \times 10^{-23} J/K \). For \( kT << E \) no excitations, \( kT >> E \) excitations. For \( E = 1 \) eV, at \( T=300 \) K, BF\~{}3 \times 10^{-17}. At \( 5000 \) K, BF\~{}0.1.
Vibration: Harmonic oscillators, levels with equal spacing. \( E_N = N \hbar \omega_0 + E_0 \), \( N=1, 2, \ldots \). \( \omega_0 = \sqrt{k/m} \).
Photon spectra: \( \gamma \)-ray, \( 10^6 \) eV, X-ray \( 10^4 \) eV, visible \( 1.8 - 3.1 \) eV, microwaves \~{}\( 10^{-4} \) eV, radio \( 10^{-6} \) eV.

Sec. 9.1-9.5. Multiparticle system
cm-point system: Momentum \( P_{\text{cm}} = M v_{\text{cm}} \), where \( P_{\text{cm}} = P_{\text{tot}} = \sum_i p_i \). \( M = \sum_i m_i \). It moves with \( v_{\text{cm}} \).
Momentum principle applied to the cm-point system: \( \frac{dP_{\text{cm}}}{dt} = F_{\text{net,ext}} \).
Real system: \( \Delta E = \Delta K_{\text{trans}} + \Delta K_{\text{rel}} + \Delta U \). \( K_{\text{trans}} = \frac{M v_{\text{cm}}^2}{2} = \frac{p_{\text{cm}}^2}{2M} \), \( K_{\text{rel}} = K_{\text{rot}} + K_{\text{vib}} \), \( U_g = M g y_{\text{cm}} \).
\( K_{\text{rot}} = \frac{1}{2} I \omega^2 \), where \( \omega = 2\pi/T \), with \( I = \sum_i m_i r_i^2 \), \( I_{\text{ring}} = m R^2 \), \( I_{\text{disk}} = \frac{1}{2} m R^2 \), and \( I_{\text{rod}} = \frac{1}{12} M L^2 \).