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

Sec. 6.4-6.17. Pair-interactions and potential energy of multiparticles: $E_{sys} = \Sigma_i(m_i c^2 + K_i) + \Sigma_{i<j} U_{ij}$.

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 $F_x = -dU(x)/dx$.
- $U(r) \to 0$ as $r \to \infty$. $|u(r)|$ increases, as $r \to 0$. Attractive $U < 0$, repulsive $U > 0$.

Gravity: $U(r) = -\frac{GmM}{r}$, $F = -\frac{GmM}{r^2}$. Electricity: $U(r) = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r}$, $F = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$.

Satellite (circular orbit). Centripetal force: $mv^2/r = GmM/r^2$. $K = (1/2)GmM/r$. $K + U = -(1/2)GmM/r$.

Sec. 7.1-7.11. Energy in Macroscopic Systems

Ideal spring: $U(x) = (1/2)kx^2$, $F_{spring} = -kx$. $K + U = mv_{max}^2/2 = kA^2/2$. $x = Acos\omega t$, $\omega = \sqrt{k/m}$.

Morse potential: $U_{morse} = E_M \left[1 - e^{-\alpha(r-r_{eq})}\right]^2 - E_M$

$U(r)$ is a function of position coordinate only. It is independent of the paths how r is reached.

Energy principle: $\Delta E_{therm} = Q + W$, $E_{therm} = CmT$, where C is specific heat of m in units of J/g/K.

Dissipations: Terminal velocity at $F_{air} = mg$. $\mathbf{F}_{air} = (-1/2)C\rho A v^2 \hat{\mathbf{v}}$. Friction: $F_{max}^{static} = \mu_s N$, $F^{kin} = \mu N$.

Sec. 8.1-8.7. Energy Quantization and photons

When W_{surr} is negligible, the system is specified by its E'-state content, where $E' \equiv K + U$.

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 $E' < 0$, minimun r not well defined. Micro system has discrete bound states and has a ground state which defines r_{min}.

Frank-Hertz experiment: $e + Hg \to e + Hg^*$ It illustrates the discreteness of the 2nd level of Hg atom.

Photons: Light is made of wave-energy packets called photons (symbol γ). Size is $\sim \lambda$ (wavelength).

$E_\gamma = \hbar\omega = hc/\lambda = 1240(eVnm)/\lambda$, with $\hbar = h/2\pi$. The Planck constant $h = 6.6 \times 10^{-34} Js$.

- Atomic excitations: $X + atom \to X + atom^*$. Energetic X may kick ground state e to an excited level.
- Emission: Decay from ith level leads to emission of γ with energy $E_\gamma = E_i - E_j$, $1 < j < i - 1$.
- Absorption: Electron at ground 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=300K, BF$\sim 3 \times 10^{-17}$. At 5000K, BF$\sim$0.1.

Vibration: Harmonic oscillators, levels with equal spacing. $E_N = N\hbar\omega_0 + E_0$, N=1, 2, ... $\omega_0 = \sqrt{k/m}$.

Photon spectra: γ-ray, 10^6eV, X-ray 10^4eV, visible $1.8 - 3.1$eV, microwaves $\sim 10^{-4}$eV, radio 10^{-6}eV.

Sec. 9.1-9.5. Multiparticle system

cm-point system: Momentum $\mathbf{P}_{cm} = M\mathbf{v}_{cm}$, where $\mathbf{P}_{cm} = \mathbf{P}_{tot} = \Sigma_i \mathbf{p}_i$. $M = \Sigma_i m_i$. It moves with $\mathbf{v}_{cm}$

Momentum principle applied to the cm-point system: $\frac{d\mathbf{P}_{tot}}{dt} = F_{net,ext}$.

Real system: $\Delta E = \Delta K_{trans} + \Delta K_{rel} + \Delta U$. $K_{trans} = \frac{Mv_{cm}^2}{2} = \frac{P_{cm}^2}{2M}$, $K_{rel} = K_{rot} + K_{vib}$, $U_g = Mgy_{cm}$.

$K_{rot} = \frac{1}{2}I\omega^2$, where $\omega = 2\pi/T$, with $I = \Sigma_i m_i r_i^2$, $I_{ring} = mR^2$, $I_{disk} = \frac{1}{2}mR^2$, and $I_{rod} = \frac{1}{12}ML^2$.