Rough list of topics for Quantum Mechanics 1, CMI Spring 2011.

1. Introductory remarks: why quantum theory? $\langle 1 \rangle$
2. Review of classical mechanics $\langle 3 \rangle$
   (a) Newton's equation
   (b) Generalized coordinates, degrees of freedom,
   (c) Energy, Hamiltonian, momentum, angular momentum
   (d) Hamilton's equations
   (e) Conserved quantities
   (f) Action principle and Lagrangian formulation
3. Basic concepts of waves $\langle 3 \rangle$
   (a) Traveling, standing, sinusoidal, monochromatic, plane and spherical waves
   (b) Amplitude, wave number, frequency, wave vector and intensity
   (c) Wave equations
   (d) Wave packets and width of wave packet
   (e) Dispersive waves, group velocity of wave packet
4. Experimental basis & historical development of quantum mechanics
   (a) Quanta of light/radiation $\langle 3 \rangle$
      i. Black body radiation & Planck hypothesis
      ii. Photoelectric effect
      iii. Compton effect
   (b) Wave and quantum properties of matter $\langle 5 \rangle$
      i. Discrete atomic spectra and stability of the atom
      ii. Bohr Model of the atom
      iii. Franck-Hertz experiment
      iv. Raman scattering and discrete molecular spectra
      v. de Broglie hypothesis on matter waves
      vi. Electron diffraction: Davisson, Germer & Thompson experiment
      vii. Double slit interference experiment: wave function as a probability amplitude
      viii. Wave-particle duality and complementarity principle
5. Schrödinger equation, postulates and formulation of quantum mechanics $\langle 7 \rangle$
   (a) Schrödinger equation from de Broglie matter wave hypothesis $\langle \frac{1}{2} \rangle$
   (b) Wavefunction, probability density and current $\langle \frac{1}{2} \rangle$
   (c) Superposition principle and vector space of states $\langle \frac{1}{2} \rangle$
   (d) Dirac Delta function $\langle \frac{1}{2} \rangle$

(e) Expectation values of observables in a state $\langle \frac{1}{2} \rangle$

(f) Ehrenfest's theorem $\langle \frac{1}{2} \rangle$

(g) Hilbert space of quantum states, Dirac bra-ket notation $\langle 1 \rangle$

(h) Position eigenstates $\langle \frac{1}{3} \rangle$

(i) Momentum eigenstates $\langle \frac{1}{3} \rangle$

(j) Relation between $\hat{x}$ and $\hat{p}$: Heisenberg commutation relation and uncertainty $\langle \frac{1}{3} \rangle$

(k) Hermiticity of observables $\langle \frac{1}{2} \rangle$

(l) Collapse of the wavefunction/measurement and probability postulate $\langle \frac{1}{4} \rangle$

(m) Summary of postulates of quantum mechanics $\langle \frac{1}{4} \rangle$

(n) Energy eigenstates: Time-independent Schrödinger equation $\langle \frac{1}{2} \rangle$

(o) Time evolution operator $\langle \frac{1}{2} \rangle$

6. One dimensional quantum mechanical models $\langle 8 \rangle$

   (a) Particle in an infinite square well $\langle 1.5 \rangle$

   (b) Free particle $\langle 2 \rangle$

      i. plane waves

      ii. minimal uncertainty gaussian wave packet

   (c) Harmonic oscillator $\langle 4.5 \rangle$

      i. Variational approach

      ii. Algebraic approach: creation and annihilation operators

      iii. Analytic approach: Hermite polynomials

7. Some general properties of 1 dimensional quantum systems $\langle 3 \rangle$

   (a) Parity $\langle \frac{1}{2} \rangle$

   (b) Time development of expectation values $\langle \frac{1}{4} \rangle$

   (c) Symmetries and conserved quantities: parity, space and time translations $\langle \frac{1}{2} \rangle$

   (d) Energy-time uncertainty relation $\langle \frac{1}{4} \rangle$

   (e) Absence of degenerate bound states in 1d $\langle \frac{1}{2} \rangle$

   (f) Schrödinger vs Heisenberg pictures & equations of motion $\langle \frac{1}{2} \rangle$

   (g) Complete sets of commuting observables $\langle \frac{1}{2} \rangle$

8. Models with bound and scattering states in 1 dimension; Tunneling $\langle 3 \rangle$

   (a) Delta function potential: bound states $\langle \frac{1}{2} \rangle$

   (b) Reflection and Transmission coefficients $\langle \frac{1}{2} \rangle$

   (c) Scattering against a delta function potential $\langle \frac{1}{2} \rangle$

   (d) Bound states of finite square well $\langle 1 \rangle$

   (e) Scattering against a rectangular barrier $\langle \frac{1}{2} \rangle$

9. Simple problems in two dimensions $\langle 1 \rangle$

   (a) Free particle in two-dimensions
   (b) Two dimensional infinite square well
   (c) Parity in two dimensions
   (d) Two dimensional harmonic oscillator

10. Quantum mechanics in 3d: Central potentials $\langle 5 \rangle$

   (a) Free particle in Cartesian coordinates, hamiltonian in polar coordinates $\langle \frac{1}{3} \rangle$
   (b) Basic properties of angular momentum $\langle \frac{2}{3} \rangle$
   (c) Angular momentum and rotations $\langle \frac{1}{3} \rangle$
   (d) Free particle in spherical coordinates, radial momentum $\langle \frac{1}{3} \rangle$
   (e) Hermiticity and positivity of free particle hamiltonian $\langle \frac{1}{3} \rangle$
   (f) Conservation of angular momentum in a central potential $\langle \frac{1}{3} \rangle$
   (g) Separation of variables for particle in central potential $\langle \frac{1}{3} \rangle$
   (h) Preview of spectrum of angular momentum L^2, L_z. $\langle \frac{1}{3} \rangle$
   (i) Free particle radial eigenfunctions. $\langle \frac{1}{2} \rangle$
   (j) Particle in a spherical well. $\langle \frac{1}{2} \rangle$
   (k) Joint spectrum of L^2 and L_z: spherical harmonics $\langle \frac{1}{3} \rangle$
   (l) Eigenvalues of L^2 and L_z by ladder operators $\langle \frac{1}{3} \rangle$
   (m) Spectrum of Hydrogen atom, radial eigenfunctions $\langle \frac{1}{3} \rangle$