

Basics of Wave and Quantum Mechanics for Engineers
ECE 520.457, Fall 2008

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Class Notes: Table of content (first semester)

0. *Useful constants and relations*
1. *Introduction*
 - 1.1. Who ordered Quantum Mechanics?
 - 1.2. What was wrong with a classical old-shoe?
 - 1.3. Quantum mechanics in a nut-shell.
2. *Classical mechanics of particles*
 - 2.1. Basic notions and laws of classical mechanics
 - 2.2. Harmonic potential and oscillator
 - 2.3. Coulomb potential
 - 2.4. Angular momentum
 - 2.5. Relativistic mechanics
3. *Classical mechanics of waves*
 - 3.1. Waves as the excitation of continuous medium
 - 3.2. Waves in an infinite string and plane EM waves
 - 3.3. Eigen-modes and oscillations of confined waves
 - 3.4. Spatial wave-equation for eigen-modes
 - 3.5. Waves as two-component process → wave velocity as a matrix
4. *Waves in electrodynamics*
 - 4.1. EM wave equation
 - 4.2. Diffraction; "paraxial" approximation and Gaussian beams
 - 4.3. Wave interference
 - 4.4. Dispersion; frequency-dependent propagation; plasma formula
 - 4.5. Simplest waveguides and plasma analogy
 - 4.6. Boundary conditions; reflection, transmission, resonators
5. **Operators ↔ dispersion relations ↔ wave equations**
 - 5.1. Algebraic equation replaces a differential equation
 - 5.2. Dispersion relations and wave equations
6. **Quantum mechanics -- at last!**
 - 6.1. Building it from point-particle & wave mechanics: Schrödinger equation
 - 6.2. Planck constant and Heisenberg uncertainty principle.
 - 6.3. Conservation of "total quantum probability" or "number of particles"
 - 6.4. Physical limitations/conditions on wave function

- 6.5. Quantum mechanical operators and mean values
- 6.6. Properties of operators; general uncertainty relations
- 6.7. Relativistic quantum mechanics
- 7. **Time-dependent problems: the motion of a QM wave packets in a free space**
 - 7.1. Spatio-temporal "diffraction" of a Gaussian wave-packet
 - 7.2. Mean values and $\delta x \cdot \delta p$ uncertainty
 - 7.3. The energy of a Gaussian wave-packet
 - 7.4. Quantum phase: two-slit Young interference
 - 7.5. A "kicked" wave-packet; group and phase velocity in QM
- 8. **"Philosophical" matters**
 - 8.1. Measurements: QM and CM have to coexist
 - 8.2. Quantum wave collapse
- 9. **Discrete QM bound states in a box; eigen-energies and eigen-functions**
 - 9.1. Quantum confined structures and time-independent Schrödinger equation
 - 9.2. Box with infinite walls
 - 9.3. Finite box and boundary conditions
 - 9.4. "Baby-states" of a finite box potential
 - 9.5. Delta-function potential: a single-level system
- 10. **Reflection, transmission and tunneling in 1D-scattering**
 - 10.1. Plane waves in QM
 - 10.2. Reflection and transmission at a single boundary.
 - 10.3. Resonances in the reflection from quantum well and barrier
 - 10.4. Tunneling through a finite barrier
- 11. **Quantum harmonic oscillator**
 - 11.1. Schrödinger equation and ground state wavefunction
 - 11.2. Excited state wavefunctions
 - 11.3. WKB approximation: spatial oscillations of wavefunction
 - 11.4. Quantum and classical distribution of probabilities
 - 11.5. Harmonic oscillations
 - 11.6. They do it in optics too!
 - 11.7. How many quantum states for one classical trajectory?
 - 11.8. Secondary quantization: creation and annihilation as QM phononics
- 12. **Bohr's hydrogen atom**
 - 12.1. Bohr's back-of-the-envelope energy level calculation
 - 12.2. *H*-like atom and ions
 - 12.3. Ground-state of *H*-atom
 - 12.4. Eigen-wavefunctions of *H*-atom; quantum numbers