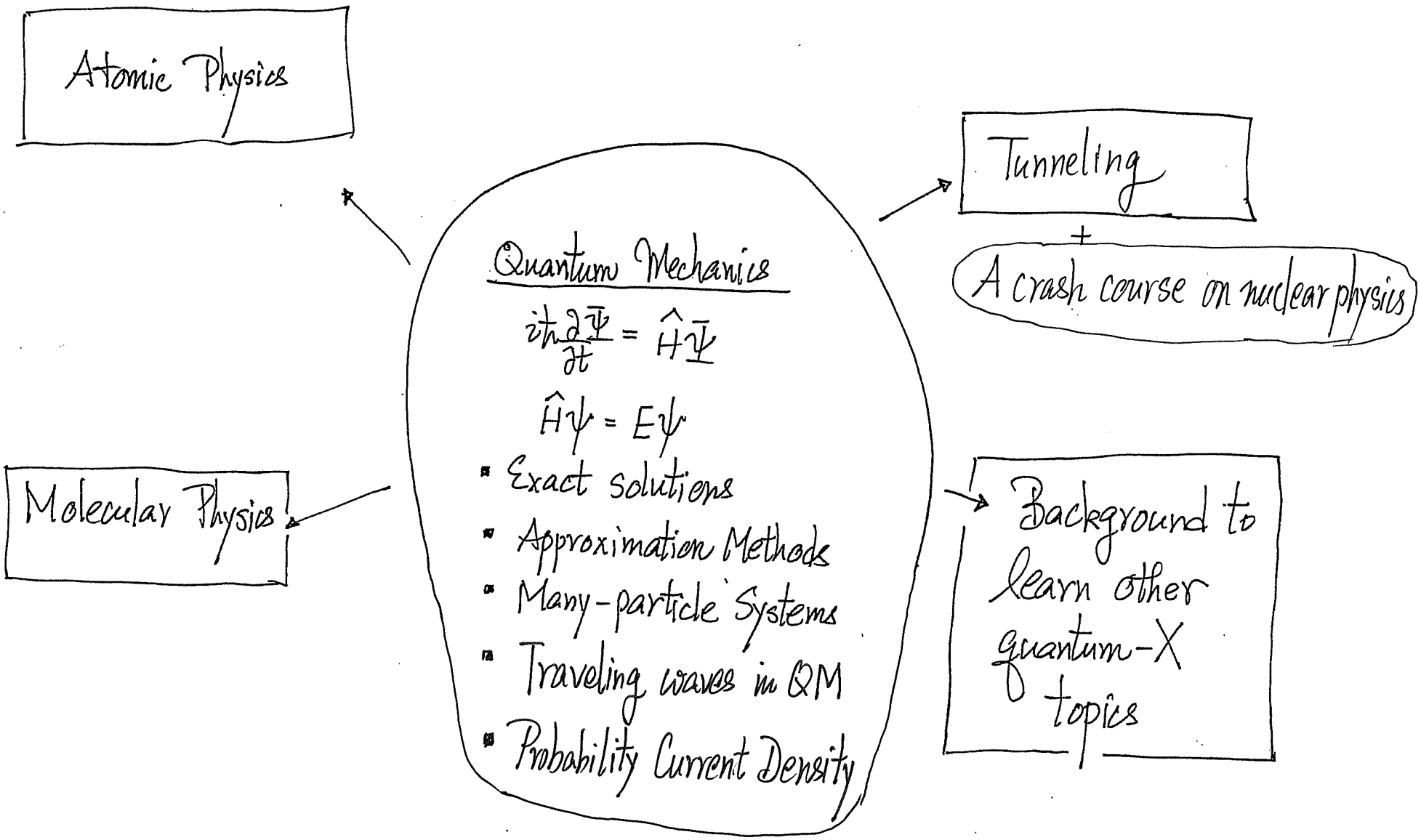

Atomic Physics
Molecular Physics
Quantum Mechanics
$i\hbar\frac{\partial\Psi}{\partial t} = \hat{H}\Psi$
$\hat{H}\psi = E\psi$
Exact solutions
Approximation Methods
Many-particle Systems
Traveling waves in QM
Probability Current Density
Tunneling
+
A crash course on nuclear physics
Background to learn other quantum-X topics

Quantum Mechanics

- $i\hbar \frac{\partial \Psi}{\partial t} = \hat{H}\Psi$
- $\hat{H}\psi = E\psi$
- Exactly Solvable Problems
  [not many]
  Wells, SHO, H-atom
  Turning TISE into a Big Matrix
- Probability Current Density
- Approximation Methods
  (a) Variation Principle
  (b) $\hat{H} = \hat{H}_0 + \hat{H}'$
  Non-degenerate perturbation theory
  • 1st order • 2nd order
  (c) Degenerate perturbation theory
  (d) Time-dependent perturbation theory
  (e) Handling many-electron problems
  (f) Born-Oppenheimer approximation (molecules)
  (g) Simple Matrix Maths

Physics of Atoms

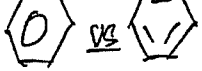
H-atom (applicable to other atoms)

- relativistic correction
- spin-orbit coupling
- Zeeman effect
  - Weak field { spin-orbit then $\vec{B}$
  - Strong-field { $\vec{B}$ then spin-orbit
- Hyperfine structure
  - electron j - nucleus spin coupling
  - radio astronomy
- Transitions
  - time-dependent perturbation
  - Selection rules
  - Einstein's A and B coefficients
  - Natural broadening, line shape
  - Lasers

Many-electron Atoms

- Hamiltonian, many-electron problem
- Independent-particle approximation
  - reduce to single-electron problem
  - Self-consistent field [Hartree]
- Many-electron Wavefunction
  - Pauli Exclusion Principle
  - Anti-symmetric wavefunction
- Coulomb and Exchange integrals
- Periodic table
- Fermions avoid each other, Bosons like each other

Physics of Molecules

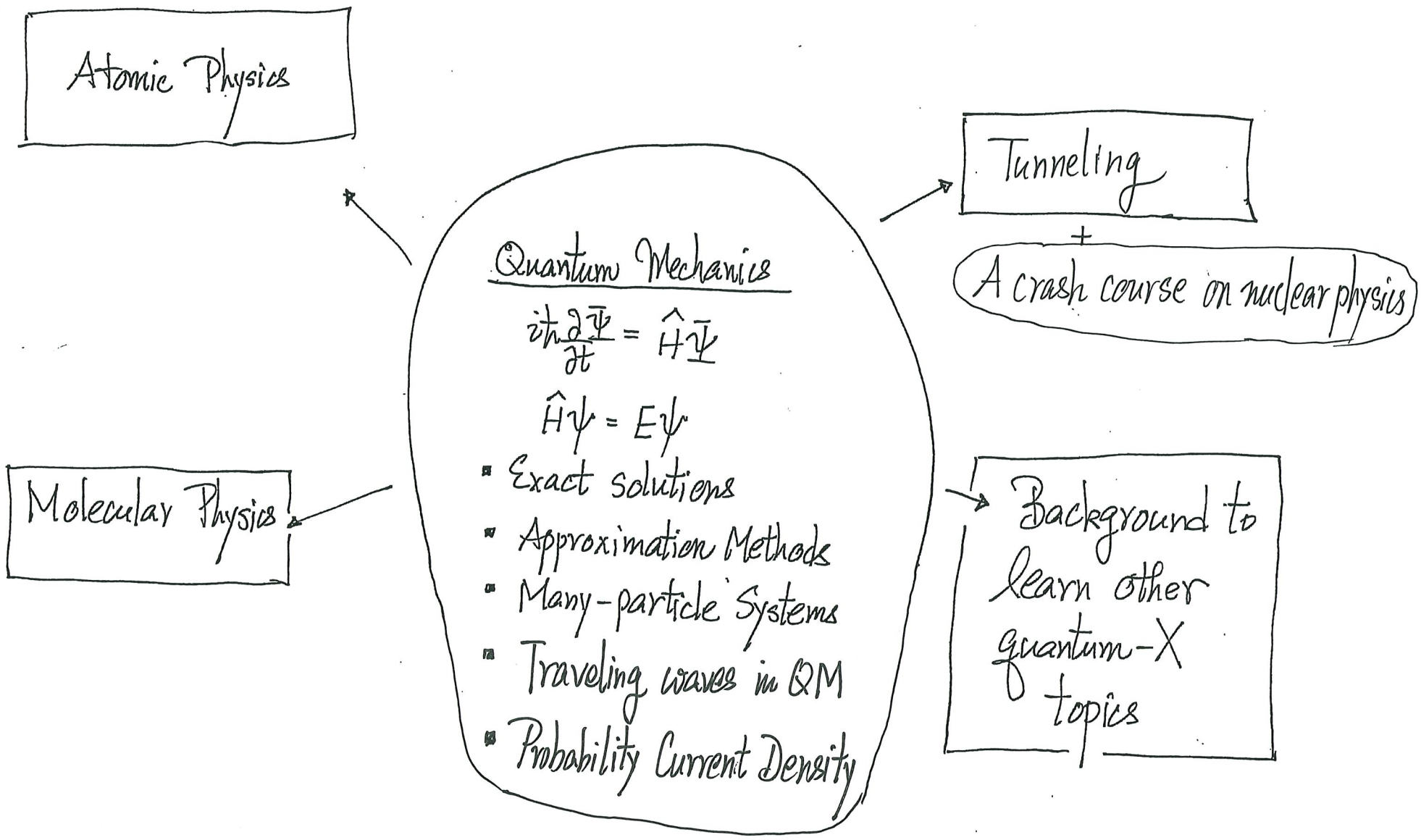
- Potential energy profile for binding
- Energetics of ionic bond
- Hamiltonian, many-nuclei many-electron problem
- Born-Oppenheimer Approximation
  - Electron problem with fixed nuclei
  - Vibration and rotation after solving electron problem
- LCAO-MO
  - related to matrix formulation
- H_2^+
- H_2 [Coulomb and exchange integrals]
- MO: filling electrons with Pauli Exclusion Principle
- σ-bonds and π-bonds
- directional feature of covalent bonds [sp, sp^2, sp^3]
- Hückel theory of π-electrons 
- Molecular Spectrum
  - Electrons form bond and provide the "spring"
  - Vibrational and rotational states
  - Transitions between molecular levels give molecular spectrum
  - Spectrum { bond length, bond strength

Tunneling

- Traveling waves in QM and their normalization
- Continuity Equation & Probability current density
- Tunneling: Transmission & Reflection Coefficients
- Applications: α-decays, nuclear fusion, STM, field emission, resonant tunneling, quantum cascade lasers, ...

A crash course in Nuclear physics

- Binding energy & B/A vs A curve
- Nuclear force, Yukawa potential & Yukawa meson
- Independent Particle Approximation
- Spin-orbit interaction & Magic numbers
- Segre Chart and various decays
- Statistical nature of decays, life time and half life
- Q-value
- p-p cycle in stars (fusion)



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