Massachusetts Institute of Technology

Department of Physics

Physics 8.04, Spring 1997 February 5, 1997

# Quantum Physics I, Spring 1997

Note: The notations in square brackets give chapter and section readings roughly corresponding to the material in the outline. The abbreviations are RH = *Resnick and Halliday* (section numbers), G = *Gasiorowicz* (read section(s) contained with in given range of pages), H = *Heisenberg* (section numbers), FT = *French and Taylor* (section numbers), CN = class notes given out in lecture and provided on the web.

Many thanks to Dicle Yeşilleten (U'97) for her help, which was invaluable in the production of this syllabus.

## Syllabus

**I. Overview: Following the Scientific Method**

**II. The Experimental Evidence**

- A. Identity of the Basic Building Blocks of the World Around Us
  1. Electrons (JJ Thomson/RA Millikan) [FT 1.3-1.4, H I2a]
  2. Nuclei (E. Rutherford) [RH 7.1-7.3]
  3. Electromagnetic Energy/Radiation (comment)
- B. Behavior of the Building Blocks
  1. Nuclei (comment)
  2. Electromagnetic Energy
     - Classical E&M (recall)
     - Photoelectric Effect (A Einstein) and related effects [RH 5.1-5.3, 5.6, G 9]
     - Single slit experiments (GI Taylor)
     - Poisson statistics [CN "Statistics"]
     - Compton Scattering [RH 5.4, H I2d, G 11]
  3. Electrons
     - JJ Thomson (recall)
     - Davisson-Germer Interference [CN "de Broglie," RH 6.2, H I2b-c, G 13-15]
     - GP Thomson Interference

**III. Exploration of Qualitative and Semiquantitative Pictures**

- A. de Broglie Hypothesis [CN "de Broglie"]

B. Heisenberg Uncertainty Principle (HUP) [RH 6.5-6.7, CN "HUP", H II, G 33-38]

- Energy of the Hydrogen atom [CN "HUP"]
- Atomic Spectra [RH 7.4]
- Franck-Hertz Experiment [RH 4.7, H I2e]

C. Semiclassical Quantization and the Correspondence Principle [CN "Bohr-Sommerfeld," [RH 7.7, 7.5, G 15-21]

- X-ray Spectra (Moseley) [FT 1.10]

## IV. Constructing a Quantitative Theory Consistent with the Experimental Evidence

A. "Kinematics": The Wavefunction/Operator Framework [H IV3]

1. Wavefunctions/Fourier Transforms [CN "States and Observables"]
2. Operators [CN "Quantum Operators", G 45-46, 114-118]

B. "Dynamics": Time-Dependent Schrödinger Equation (TDSE) [CN "TDSE", G 49-50]

1. Verify consistency with probabilistic interpretation: probability currents, [CN "TDSE", G 42-45]
2. Verify consistency with the correspondence principle: Ehrenfest's Theorem, [G 125-127]
3. Computer solutions as examples

## V. Tools to Apply the Theory: Solving the TDSE

A. Separation of Variables: Reduction to Time-Independent Schrödinger Equation (TISE) [CN "TISE"]

B. Time Independent Schrödinger Equation [CN "TISE"]

- Qualitative solutions (1d) [FT 3.11]

## VI. Predictions of the Theory: Solutions to Schrödinger's Equation

A. Scattering States in One Dimension [CN "Scattering"]

1. Wave packets [G 27-31]
   - Gaussian packet
   - General Packet and Stationary phase
2. Reflection at a step/time delay, [G 74-85, 86-89]
3. Feynman diagrams and sum over histories
4. Symmetry and resonance

B. Bound States in One Dimension

1. General features – eigenstate expansions, energy representation [CN "TISE", G 60-63]
2. Piecewise constant potentials [CN "Finite Square Well", [G 58, 67-70, 89-93]
3. $\delta$-function potential [G 93-99]

4. Simple Harmonic Oscillator [CN "SHO", G 103-108]
    - dimensional analysis
    - momentum representation/self-transform property of solutions
    - full power series solution