

University of Sydney

School of Physics

PHYS 3060 Quantum Mechanics & Physics Lab

Second Semester 2006

Quantum Mechanics: Module Outline

Associate Professor Brian James
School of Physics, Room 216A
B.James@physics.usyd.edu.au

This module consists of **19 lectures**. The following documents are provided, and will also be available via the *Senior Physics webpage*: Lecture notes; a set of problems from which the assignment questions will be selected; powerpoint slides.

General goals of this module

- To show how quantum mechanics describes the internal energy levels of atoms and molecules
- To explain the quantum mechanical description of the interaction of radiation with atoms and molecules
- To describe the physical consequences of the indistinguishability of identical particles
- To describe the relevance of quantum mechanics to recent advances in atomic physics (such as laser cooling, atom optics, Bose-Einstein condensation)

Timetable

See the *Senior Physics webpage*.

Textbook

There is no prescribed textbook. The following are recommended reference books.

Main reference

R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* 2nd Edition, Wiley (1985).

Other references

A.P. French and E.F. Taylor, *An Introduction to Quantum Mechanics* Thomas Nelson (1979).
B.H. Bransden and C.J. Joachain, *Physics of Atoms and Molecules* Longman (1983, 2003).
B.H. Bransden and C.J. Joachain, *Introduction to Quantum Mechanics* Longman (1989, 2000)

Popular books

- J. Gribben, *In Search of Schrödinger's Cat*, Corgi (1985)
J. Gribben, *In Search of Schrödinger's Kittens*, Phoenix (1996)
G. Milburn, *Quantum Technology*, Allen and Unwin (1996)

Web resources

Copies of handout material will also be available in pdf format via the Senior Physics website.

Assignments

There will be two assignments for this module. See the *Senior Physics website* for the assignment schedule.

Assessment

Assignments:	25%
Final exam:	75%

Module definition

(with reference to relevant sections of Eisberg & Resnick)

- 1. Bohr's model of the atom (revision)**
Rutherford's model; Bohr's postulates; quantisation; energy levels; finite nuclear mass; emission and absorption of radiation; hydrogen spectrum; the correspondence principle; problems with the old quantum theory (E&R §4-4 to 4-8)
- 2. Schrödinger's equation for a one-electron atom**
Central potential; separation of the time-independent equation; solution of the equations; eigenvalues; eigenfunctions; quantum numbers, degeneracy; probability densities (E&R §7-1 to 7-7)
- 3. Operators, eigenfunctions & eigenvalues**
Representing physical quantities as operators, Schrödinger's equation as an eigenfunction problem, eigenfunctions, eigenvalues
- 4. Orbital angular momentum**
Quantisation of angular momentum; operators for magnitude and z component of orbital angular momentum; expectation values; vector model (E&R §7-8, 7-9)
- 5. Electron spin and fine structure of energy levels**
Orbital magnetic dipole moments; Stern-Gerlach experiment; electron spin; spin-orbit interaction; total angular momentum; rules for addition of angular momenta; fine structure of hydrogen energy levels; Dirac's fine structure formula; spectroscopic notation; hyperfine structure, hydrogen 21 cm line (E&R §8-1 to 8-6)
- 6. Emission of radiation**
Radiation from a classical oscillating dipole; time dependent Schrödinger's equation; time dependence of a stationary state; simple model for radiative transition; transition probability; allowed and forbidden transitions; metastable states; spontaneous emission, stimulated emission, absorption; Einstein relations; laser action; nuclear magnetic resonance, electron spin resonance (E&R §8.7, §11.7, examples 10-6, 11-3)

7. Identical particles

Identical particles; fermions and bosons; symmetry of wave functions; Pauli Exclusion Principle; singlet and triplet states; exchange energy, energy levels of helium atom (E&R §9-1 to 9-4); Bose-Einstein condensation (E&R §11-10); other examples: ferromagnetism (E&R §14-4), lasers.

8. Multielectron atoms

Hartree's method; electron configuration; shells, subshells; approximate expressions for energies of shells; X-ray line spectra; Moseley's measurements; alkali atoms; *LS* coupling, selection rules; normal and anomalous Zeeman effect, Paschen-Bach effect (E&R §10-1 to 10-7)

9. Molecules

Ionic and covalent bonds; potential curves for diatomic molecules; rotational spectra; vibrational-rotational spectra; populations of excited rotational and vibrational states; electronic band spectra; Franck-Condon principle; Raman spectra (E&R §12-1 to 12-8)

10. Recent developments

Atom traps; laser cooling; Bose-Einstein condensation; atom optics

Updated: June 16, 2006