Struttura della Materia II Syllabus

Giovanni Moruzzi Academic Year 2010/2011

1. Missing information

- 1.1 Missing information for a discrete number of equally probable choices
- 1.2 Choices with known probabilities
- $1.3\,$ Missing information for a choice in the continuum

2. Statistical mechanics

- 2.1 Classical statistics
 - 2.1.1. State of a classical system and physical quantities
 - 2.1.2. Active and passive transformations
 - 2.1.3. Time evolution
 - 2.1.4. Statistical treatment
 - 2.1.5. Schrödinger representation
 - 2.1.6. Heisenberg representation
- 2.2 Quantum statistics
 - 2.2.1. Sate of a quantum system and physical quantities
 - 2.2.2. Time evolution
 - 2.2.3. Statistical treatment and density matrix

3. Choice of probability

- 3.1 First postulate: a priori probability
- 3.2 Available information
- 3.3 Second postulate: constrained maximum of missing information
- 3.4 Maxima subject to constraints: Lagrange multipliers
- 3.5 Available information in classical statistics
- 3.6 Identical particles in classical statistics
- 3.7 Available information in quantum mechanics

- 3.8 Identical particles in quantum mechanics
- 3.9 Parttion function

4. Missing information and entropy

- 4.1 Conserved quantities
- 4.2 Perfect gas

5. Grand canonical ensemble

- 5.1 Introduction
- 5.2 Classical mechanics
 - 5.2.1. Unknown, or variable number of identical particles
 - 5.2.2. The physical quantity number of particles
 - 5.2.3. Entropy
 - 5.2.4. Grand canonical ensemble for the classical perfect gas
- 5.3 Quantum mechanics
 - 5.3.1. Quantum perfect gas
 - 5.3.2. Chemical potential
 - 5.3.3. Occupation numbers

6. Fluctuations of statistical quantities

- 6.1 Fluctuation amplitudes
- 6.2 Fluctuations of occupation numbers

7. Random walk

- 7.1 Introduction
- 7.2 Mathematical formulation in one dimension
- 7.3 Expected position
- 7.4 Statistical dispersion
- 7.5 Probability distribution for large N
- 7.6 Reflecting and absorbing walls
- 7.7 Statistical moments of a random variable
- 7.8 Central limit theorem

8. Stochastic processes

- 8.1 Introduction
- 8.2 Ensemble average
- 8.3 Autocorrelation and spectral density

- 8.3.1. Mathematical overview
- 8.3.2. Stationary stochastic processes
- 8.3.3. Shot noise
- 8.3.4. 1/f nose
- 8.3.5. Photocountings
- 8.4 Fokker-Planck equation
- 8.5 Brownian motion
- 8.6 Nyquist theorem

9. Principles of laser action

- 9.1 Einstein's derivation of Planck's law
- 9.2 Propagation of a light beam in matter
- 9.3 Rate equations for the laser effect
 - 9.3.1. Population inversion
 - 9.3.2. Rate equations for the photon density in a laser
 - 9.3.3. Rate equations for the population densities of the energy levels involved in a laser process
 - 9.3.4. Other possible laser systems
- 9.4 Semiconductor lasers

10. Radiation fluctuations and interference

- 10.1 Photon fluctuations below and above laser threshold
- 10.2 Complex representation of electromagnetic fields
- 10.3 Interference
- 10.4 The beam-splitter
- 10.5 Mach-Zehnder interferometer
- 10.6 Michelson interferometer
- 10.7 Fourier-transform spectroscopy
- 10.8 Line shapes
- 10.9 Michelson-Morley experiment
- 10.10 Young's interferometer and spatial coherence
- 10.11 Coherence volume

11. Astronomical applications of interferometry

- 11.1 Michelson's stellar interferometer
- 11.2 Hanbury Brown-Twiss stellar interferometer
 - 11.2.1. Classical interpretation

11.2.2. Quantum-mechanical interpretation

12. Interaction of radiation with matter

- 12.1 Time-dependent perturbations
 - 12.1.1. Introduction
 - 12.1.2. Transition probability
 - 12.1.3. Constant perturbations
 - 12.1.4. Periodic perturbations
 - 12.1.5. Electromagnetic transitions within a continuum
 - 12.1.6. Fermi's golden rule
- 12.2 Second-order periodic perturbations
- 12.3 Electric-dipole transitions
- 12.4 Absorption, stimulated and spontaneous emission
- 12.5 Strong-field interactions

13. Density matrix

- 13.1 Rate equations and the principle of detailed balance.
- 13.2 Density matrix
- 13.3 Feynman-Vernon-Hellwarth representation
- 13.4 Relaxation and optical Bloch equations
- 13.5 Refraction index and absorption coefficient
- 13.6 Rate equations and line shapes
- 13.7 Atom-reservoir interactions
- 13.8 Homogeneous line broadening
- 13.9 Inhomogeneous line broadening: Doppler effect

14. Selection rules

- 14.1 Symmetry considerations
- 14.2 Electric-dipole transitions

15. Superconductivity

- 15.1 Recollections of classical magnetism
- 15.2 Magnetization work
 - 15.2.1. "Mechanical" work on the sample
 - 15.2.2. Work done by the generator
- 15.3 Recollections of thermodynamics
- 15.4 Superconductivity and critical magnetic field

- 15.5 Meissner effect
- 15.6 Perfect diamagnetism
- 15.7 Superconductivity current
 - 15.7.1. Surface currents
 - 15.7.2. Surface currents in normal conductors
 - 15.7.3. Surface currents in superconductors
- 15.8 Critical magnetic field
- 15.9 Microscopic theory

16. Magnetic cooling

- 16.1 Introduction
- 16.2 Energy
- 16.3 Entropy and magnetic cooling

17. Magnetic Resonance

- 17.1 Classical description
- 17.2 Quantum mechanical description
- 17.3 Rotating magnetic field
- 17.4 Oscillating magnetic field
- 17.5 Relaxation and Bloch equations
- 17.6 Solution of the Bloch equations for low oscillating field
- 17.7 Measurement of the transverse relaxation time ${\cal T}_2$
- 17.8 NMR spectroscopy
- 17.9 EPR spectroscopy

References

- 1 Amnon Katz, *Principles of Statistical Mechanics*, W.H. Freeman and Co., San Francisco and London, 1967, Chapters 1,2
- 2 Amnon Katz, Principles of Statistical Mechanics, W.H. Freeman and Co., San Francisco and London, 1967, Chapter 3
- 3 Amnon Katz, Principles of Statistical Mechanics, W.H. Freeman and Co., San Francisco and London, 1967, Chapter 4
- 4 Amnon Katz, *Principles of Statistical Mechanics*, W.H. Freeman and Co., San Francisco and London, 1967, Chapters 5,6

- **5** Amnon Katz, *Principles of Statistical Mechanics*, W.H. Freeman and Co., San Francisco and London, 1967, Chapter 7
- **9** Rodney Loudon, *The Quantum Theory of Light*, Oxford University Press, Oxford and New York, 2008, Chapter 1
- 10 Rodney Loudon, The Quantum Theory of Light, Oxford University Press, Oxford and New York, 2008, Chapter 3
- 17 Charles P. Slichter, *Principles of magnetic resonance*, Harper & Row, New York, Evanston and London, 1964, Chapters 1,2