Principles of Atomic and Nuclear Physics

Corso di Laurea Magistrale in Ingegneria Energetica

prof. Stefano Atzeni, A.A. 2014-2015

Materials:

- S. Atzeni: "Lecture Notes on Quantum Mechanics" (SA in the following)
- Notes by F. V. Frazzoli: "Fisica Atomica e Nucleare" (FVF)
- C. Mencuccini and V. Silvestrini, Fisica I (MS-I)
- C. Mencuccini and Silvestrini, Fisica II (MS-II)

English language text covering nearly all course topics:

- K. S. Krane, *Introductory Nuclear Physics*, John Wiley & Sons (1988)

See also

- J.K. Shultis and R. E. Faw, *Fundamentals of Nuclear Science and Engineering*, 2nd ed., CRC Press, Boca Raton (2008)

Elements of kinetic theory of gases • Microscopic interpretation of temperature and pressure • Equipartition principle • Maxwell velocity distribution function • Boltzmann's factor • Sample applications: chemical kinetics, polarization of gases	MS-I, Sec. XVII.1 – 3
Crisis of classical physics	SA, Ch. 1
Elements of special relativity • Critique of simultaneity • Postulates • Time dilatation and space contraction • Lorentz transformations • Momentum, mass, energy	SA, Ch. 2 (also MS-I, Ch. XI)
Particle behaviour and "old quantum theory" • Black body and energy quantization • Photoelectric effect and photon • Compton effect • Bohr's model of the hydrogen atom	FVF, Ch.1, pp.13 – 25 MS-II, Sec. XII.1 – 2
Material waves (De Briglie waves) • De Broglie waves • Complementarity • Wave packets • Uncertainty principles	SA, Ch. 4 FVF, Ch. 2, pp. 26 - 35

Elements of quantum mechanics
• Postulates and Schroedinger equation
• One-dimensional problems
  ○ Infinite potential well (quantization)
  ○ Finite potential well (bound states and free states)
  ○ Potential step and barrier (tunneling)
• Elementary atomic physics
  ○ Angular momentum, hydrogen atom, energy levels, quantum numbers
  ○ Concept of spin, exclusion principle, indistinguishibility
	
	SA, Ch. 5
	SA, Ch. 6
	
	SA, Ch. 7

Interaction of charged Particles and gamma radiation with matter
• Charged Particles
  o Coulomb diffusion
  o Ionization energy loss (Bethe-Bloch formula)
  o Stopping power. range and trajectory
  o Energy loss by radiation
  o Cerenkov effect
• Gamma rays
  o Photoelectric effect
  o Compton effect
  o Pair creation
	FVF, Ch. 2

Nuclei: fundamental properties • Mass, size, intrinsic angular momentum • Mss defect, binding energy, seSecation energy • Stable nuclei systematics • Drop model and semi-empirical mass formula • Notions on shell model • Width of excited levels and Breit-Wigner formula	FVF, Ch. 3
Radioactivity • Radioactive decay law, activity, mean life • Chain decays, secular equilibrium • Elements of statistics of decay • Alpha decay: semiclassical interpretation (Gamow) • Beta decay • Gamma decay: semiclassical interpretation; selection rules.	FVF, Ch. 4

Nuclear reactions
• Energy balance; threshold energy for endo-energetic reactions
• Cross-sections: differential, microscopic, macroscopic
• Sectial wave expansion
• Elementary s-wave cross-section theory
  o Potential diffusion
  o Breit and Wigner cross-section
  o "1/v" Law
	FVF, Ch. 5
	
	SA-Ch. 9

Neutron induced reactions • Compound-nucleus reactions: mechanism, qualitative discussion of the cross-section • Doppler effect • Fission: qualitative description; isotope classification • Fission reaction products • Prompt and delayed neutrons	FVF, Ch. 6, pp. 1 – 25 FVF, Ch. 7, pp. 1 – 14
Neutron slowind-down ("moderation") • Moderation by elastic diffusion: energy loss, probability distribution, lethargy • Moderator finite-temperature effects • Moderating materials	FVF, Ch. 6, pp. 25 – 32
Physical principles of fission reactors • Thermal and fast reactors • Four-factor formula • Basic kinetics and role of delayed neutrons • Breeding and conversion coefficient	FVF, Ch. 7, pp. 15 – 24
Nuclear fusion • Fusion reactions • Plasma power balance: ideal ignition tempertature; Lawson criterion • Magnetic and inertial confinement	FVF, Ch. 8