INSTITUT FOR FYSIK OG ASTRONOMI, AARHUS UNIVERSITET

Department of Physics and Astronomy, University of Aarhus

DK - 8000 Aarhus C, Denmark

Telephone :
Direct +45 89 42 3655
General +45 89 42 1111
Telefax : +45 86 120 740
e-mail : asj@phys.au.dk

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Siemens and Jensen: Elements of Nuclear Physics

Week 1: Pages 1-7, and notes

Introduction about (i) what is a nucleus, what are the ingredients, what are the simplest properties of radii and binding, that is Rutherford, mass formula and its background solid state and chemistry similarities and not atomic, (ii) where do the nuclei come from, where are they in space, why do we need to know, from Big Bang to present time.

Exercises for week 1:

Week 2: Pages 9-27, and notes

Nucleon-Nucleon interaction. Connection to QCD in general. Low-energy effective field. Nucleon-nucleon as effective interaction viewed from QCD. The deuteron bound state, two-body halos, effective range expansion, scattering length and effective range, spin dependence, isospin for one and two particles. T-matrix, radial dependence from Yukawa exchange of bosons, spin-isospin dependence.

Exercises for week 2:

Week 3: Notes

Few-body structures, especially three-body. Light nuclei, cluster structures. Halos, Borromean, Efimov, both ground and excited states, resonances, astro-related reactions and decay.

Exercises for week 3:

Week 4: Pages 43-57, and notes

Nucleon-Nucleus interaction. Scattering to give size, and phenomenological potentials, optical model is necessary, Woods-Saxon plus spin-orbit plus imaginary part from fits to experiments, mean-free path, establish one-body model.

Exercises for week 4:

Week 5: Pages 61-70, 74-88, 91-98, and notes

Selfbound nuclear systems. Mean-field potential, Fermi gas, shells, magic numbers, simple transfer, self-consistent mean-field, Hartree-Fock, translation and Gallilei invariance, correlation corrections, Jastrow, Bruckner, Effective range expansion giving Skyrme interaction, local density, density functional, nuclear matter, relation of form and parameters to mass formula.

Exercises for week 5:

Week 6: Pages 101-120, and notes

Deformations. Mean-field, independent particle model, practical parameters, deformed Woods-Saxon, oscillator, and liquid drop, Hartree-Fock and effective interactions, combine drop and independent particle model, potential energy surface structure.

Exercises for week 6:

Week 7: Pages 123-140, and notes

Residual interactions, pairing, odd-even effects, superfluidity. Simple model, general theory, Bogoliubov transformation, uniform model, Hartree-Fock-Bogoliubov. Interacting shell model to include correlations in general, Hilbert space reduction and related effective interactions.

Exercises for week 7:

Week 8: Pages 143-160, and notes

Ground state properties. Angular momentum and parity, magnetic moments, isospin for nuclear many-body system, isospin dependent potential, stability, beta-, dripline, separation energy formulae, fission, superheavies.

Exercises for week 8:

Week 9: Pages 217-240, and notes

Rotational motion. Classical to quantum picture, cranking, Roothian constraint, moment of intertia, rigid body, quantum moment of inertia, generator coordinates a la Peierls, rotational bands, selection rules, transitions, symmetries, yrast, large and small amplitude collective motion, vibrations, RPA, should be interacting boson model.

Exercises for week 9:

Week 10: Pages 245-274, 277-304, and notes

Excited states. Compound nucleus, level density, statistical strong decay, non-statistical strong decay (alpha example), fission, gamma and beta-decay.

Exercises for week 10:

Week 11: Pages within 307-348, and notes

Reactions. Heavy-ion reaction survey from small energies to speed of light, phase transitions, quark gluon-plasma. The many nuclear phases.

Exercises for week 11:

Week 12: Notes

Nuclear astrophysics, from nucleons to alpha's and protons, from alpha's and protons to light nuclei on Carbon and Oxygen-level, further on to Fe, origin and nature of rapid neutron and rapid proton process.

Exercises for week 12:

Week 13: Notes

Few-body nuclear astrophysics. Specific key reactions, sequential versus direct mechanism, A=5,8 gap, triple alpha and others, low-temperature, resonance dependence, waiting points in rp-process, other key reactions.

Exercises for week 13:

Week 14: Notes

Experimental methods and techniques, applications in medicin, material science, energy, climate, environment, dating of geological and archeological material.

Exercises for week 14:

Hilsen

Aksel Jensen