

Nuclear theory exam topics

1. Quantum mechanical description of nuclear scattering (definition of the scattering cross section; asymptotic form of the scattering wave function; radial Schrödinger equation (without derivation) and its asymptotic solutions; the method of partial waves; total cross section)
2. Bound and scattering states in central potentials (derivation of the radial Schrödinger equation; bound states in a central potential; the spatial, spin, and isospin components of the two-nucleon wave function, and their symmetry properties; list of possible two-nucleon states)
3. Nucleon-nucleon interaction (measurable properties of the deuteron and its wave function; the connection between the scattering phase shift and the potential; experimental scattering phase shifts and the central potential; the Yukawa potential and the mechanism of the interaction; the spin-dependent interaction; the tensor interaction; general form of the nucleon-nucleon interaction)
4. Electromagnetic interactions of nuclei (the transition probability and the interaction Hamiltonian; derivation of the vector Helmholtz equation of the electromagnetic field; electric and magnetic Hansen solutions; multipole expansion of the electromagnetic field; long wavelength limit; the transition probabilities and the electric/magnetic multipole transition operators; selection rules; relative sizes of the multipole transitions; recoil of the nucleus in an electromagnetic transition; sizes of the recoil energy, Doppler shift, and the natural line width)
5. Liquid drop model of nuclei (the density of nuclei; the Weizsäcker semi-empirical mass formula, and the neutron/proton ratio as a function of the mass number; the Coulomb energy; rotation and vibration of nuclei, elementary vibrational modes)
6. Fermi gas model of nuclei (the chemical potential of the nucleon, neutron and proton; the volume and symmetry energy; simple estimate of the surface energy; potential energy)
7. Harmonic oscillator shell model of nuclei (mean-field potential; available states in a harmonic potential; magic numbers; extension of the harmonic potential, level order; the shell model configuration of nuclei; the single-particle energy of the shell model; the unified model of nuclei)