FEF3380 Strongly coupled plasmas 8.0 credits

Starkt kopplade plasmor

This is a translation of the Swedish, legally binding, course syllabus.

Establishment

The official course syllabus is valid from the autumn 2026 as decided by the Faculty Board: dnr PA-2026-0008. Decision date: 2026-06-16.

Grading scale

P, F

Education cycle

Third cycle

Specific prerequisites

- Plasma physics (EF2215 Plasma Physics II or equivalent)
- Complex plasmas (FEF3360 Complex Plasmas or equivalent)
- Statistical mechanics (SI1162 Statistical Physics or SI2510 Statistical Mechanics or equivalent)

Intended learning outcomes

After the course the student shall be able to

- explain concepts that are employed for the theoretical description of the liquid state;
- apply approaches that are employed for the theoretical description of the liquid state;

- demonstrate the statistical mechanics background of liquid state theories;
- estimate the thermodynamic, static, dynamic and phase transition properties of strongly coupled plasmas;
- apply the integral equation theory to Coulomb and Yukawa one-component plasmas and expand it to other model systems of the liquid state (Lennard-Jones etc);
- appraise the isomorph theory of R-simple systems and apply it to different model systems of the liquid state.

Course contents

- Statistical mechanics I: distribution functions, the Liouville equation, the classical BBGKY hierarchy, thermodynamic equilibrium, thermodynamic ensembles and partition functions, distribution functions versus partition functions, reduced distribution functions, reduced densities, microscopic densities, correlation functions, van Hove functions, dynamic structure factor, static structure factor;
- Statistical mechanics II: basic model systems, phase diagrams of one-component systems, energy route, virial route, compressibility route, triple thermodynamic consistency, hypervirial theorem, computation of the entropy and the chemical potential, YBG hierarchy, Kirkwood superposition approximation, Born-Green equation;
- Integral equation theory of liquids I: theoretical basis, classical density functional theory, Ornstein-Zernike equation, direct correlation function, exact closure equation, bridge functions, extraction from computer simulations (Monte Carlo and Molecular Dynamics), asymptotic decay of correlations;
- Integral equation theory of liquids II: the hypernetted-chain approximation (HNC), the Percus-Yevick approach (PY), the soft mean spherical approximation (SMSA), the Verlet Modified approach (VM), the Martynov-Sarkisov approach (MS), approaches that impose thermodynamic consistency (BPGG, BB, CG, ZSEP), approaches that interpolate between theories (RY, HMSA, cross-over), approaches based on the bridge function universality ansatz (RHNC, VMHNC, FMDFT);
- Dynamic theories: time-correlation functions, classical frequency moment sum rules, classical Kubo formula, Green-Kubo relations, Einstein relations, quasi-localized charge approximation, generalized hydrodynamics, sum rule approach, continued fraction approach, mode coupling theory, replica theory, metastability and the glass transition;
- Isomorph theory: R-simple systems, strong W-U correlations, rigorous definition, basic properties, invariant quantities, Rosenfeld-Tarazona decomposition, excess entropy scaling of transport coefficients, isentropic lines in the phase diagram, isomorph invariance of bridge functions, isomorph based empirically modified HNC approach (IEMHNC);
- Strongly coupled plasma realizations: Complex plasmas, Ultra-cold neutral plasmas, High energy density matter;
- Strongly coupled plasma model systems: One-component plasmas (OCP), Yukawa one-component plasmas (YOCP), biYukawa one-component plasmas (biYOCP), OCP & YOCP at two dimensions, binary Coulomb mixtures, binary Yukawa mixtures.

Examination

- INL1 - Statistical mechanics of liquids, 1.5 credits, grading scale: P, F

- INL2 - Integral equation theory of liquids, 2.0 credits, grading scale: P, F
- INL3 - Dynamic theories of liquids, 1.5 credits, grading scale: P, F
- SEM1 - Selected topics on strongly coupled plasmas, 3.0 credits, grading scale: P, F

Based on recommendation from KTH’s coordinator for disabilities, the examiner will decide how to adapt an examination for students with documented disability. The examiner may apply another examination format when re-examining individual students. If the course is discontinued, students may request to be examined during the following two academic years.

Seminar presentations (3hp)

- Individual or in groups of two (student's choice).
- Peer grading.

Home assignments (5hp)

- Theoretical and numerical assignments.
- Individual and group work.
- Solutions discussed with teacher.

Ethical approach

- All members of a group are responsible for the group's work.
- In any assessment, every student shall honestly disclose any help received and sources used.
- In an oral assessment, every student shall be able to present and answer questions about the entire assignment and solution.