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## Theoretical Solid-State Physics, Herbstsemester 2011

### I. Introduction

I.1 Second quantization

I.2 Lattice models

I.3 Electrons in periodic potentials

### II. The electron gas

II.1 Jellium approximation: an introduction

II.2 Non-interacting electrons in the jellium model

II.3 Electron-electron interactions in Rayleigh-Schrödinger perturbation theory

II.4 Spin-polarized electron gas and its region of stability

II.5 Failure of second-order perturbation theory

### III. Green's functions

III.1 Green's function for the one-particle Schrödinger equation

III.2 Single-particle Green's functions for many-body systems

III.3 Equation of motion theory

III.4 Higher-order Green's functions; example of the Lindhard polarization function for a non-interacting electron gas

### IV. Phonons, electron-phonon interaction

IV.1 Born-Oppenheimer approximation; the self-consistent electron-nuclear problem

IV.2 Lattice dynamics in the discrete (atomistic) model; quantization into phonons; acoustic and optical phonon modes

IV.3 Continuum approach to lattice dynamics (1d example); long-wavelength modes

IV.4 Non-adiabatic corrections: electron-phonon coupling

IV.5 Polaron: the concept and generic features

### V. Response functions

V.1 The general Kubo formula

V.2 Kubo formula for the dielectric function

V.3 The random phase approximation (RPA): example of the polarization function of an interacting Fermi gas

V.4 Zero-sound collective mode

V.5 Plasmon mode in Fermi systems with Coulomb interaction

V.6 Static screening in an interacting electron gas; Friedel oscillations

### VI. Broken symmetry and collective properties

VI.1 Broken symmetry

VI.2 Goldstone modes

## **VII. Interacting electron systems in different dimensions**

- VII.1 Three dimensions: Fermi liquid theory
- VII.2 Microscopic basis of Fermi liquid theory
- VII.3 Interacting electrons in one dimension
- VII.4 The spinless Luttinger-Tomonaga model

## **VIII. Strongly correlated systems**

- VIII.1 Examples of strongly-correlated electron systems; the Hubbard model
- VIII.2 The Hubbard model at half-filling and the Mott-Hubbard insulators
- VIII.3 Ferromagnetic and antiferromagnetic orders: similarities and differences, low-energy excitations
- VIII.4 Quantization of spin waves: the Holstein-Primakoff transformation; quantum fluctuations in the Néel state
- VIII.5 Spin ordering at weak coupling: spin density waves