Review questions I

1. What is primitive cell, primitive vectors of crystal lattice?
2. Give primitive vectors of the SC-, BCC- and FCC-lattices and describe those lattice structures.
3. What is the Wigner-Seitz cell?
4. What is reciprocal lattice? Crystalline planes?
5. How to extract information about crystal structure from difraction data?
6. Prove that the reciprocal of simple hexagonal Bravais lattice is also simple hexagonal one. Derive reciprocal lattice constants and orientation of the reciprocal lattice.
7. What is the difference between molecular and ionic crystals?
8. Describe electron density distribution in covalent crystals and metals. What causes electron delocalization?
9. What is the Fermi energy? Fermi momentum? Express these quantities through electron density.
10. Derive equation for density of states of 3D (2D, 1D) electrons.
11. Calculate total energy, pressure of the Fermi gas at T=0.
12. Calculate shift of chemical potential of the free electrons due to the change of number of electrons by one.
13. Derive the Fermi distribution. What is the low-temperature limit for free electrons? Give an estimate for corresponding temperature for typical metals.
14. Calculate specific heat of the Fermi electrons, explain the concept of "effective" electrons.
15. Calculate two first terms in expansion of the heat capacity of free electrons at low temperature.
16. Calculate paramagnetic susceptibility of the Fermi gas.
17. Calculate Curie paramagnetic susceptibility. What is the difference between Curie paramagnetism and Pauli paramagnetism? Why are they different?
18. How to cool spins?
19. Define and discuss: Bloch wave function, crystal momentum, band structure.

20. Discuss the differences of the Sommerfeld- and Bloch descriptions of the electron states in a crystal. In particular, focus on quantum numbers, the range of quantum numbers, the energy, the velocity, and the structure of the wave functions.
21. Derive Bloch's theorem.
22. How many Bloch states are there in 1BZ?
23. Explain the reduced and the extended zone scheme.
24. What is the basic assumption behind the "nearly-free-electron approximation"?
25. Which electron states are most influenced by a weak periodic potential?
26. Sketch the energy bands in a one-dimensional metal in the extended, reduced, and repeated zone scheme for free electrons and according to the nearly free electron approximation.
27. Find density of states at the bottom of anisotropic conduction band (different effective masses in x-, y- and z-directions). Find density of states at a saddle point (one of the effective masses is negative, while other two are positive).
28. Define the Brillouin zones in terms of Bragg planes.
29. What is the basic idea behind the tight-binding method? What it can be used for?
30. Sketch how the energy levels change as atoms condense to form a crystal solid.
31. What is a Wannier function?
32. Compare tight-binding approximation and nearly free electron approximation. What are advantages of each method?
33. What are the differences in band structure between metals, semiconductors, and isolators?
34. Derive equation for the velocity of Bloch electron.
35. What is the density of states in a band? What are van-Hove singularities?
36. What is the effective mass tensor?
37. Explain the concept of hole.
38. Write down the semi-classical equation of motion for the velocity and crystal momentum.
39. Why would the conductivity of a perfect crystal be infinite? What is the source of the electrical resistance in metals?

40. What are Bloch oscillations?

41. Describe the motion of an electron in a crystal in a constant magnetic field.

42. Derive quasiclassical quantization equation for Bloch electrons in a magnetic field.

43. What is the Landau quantization? Calculate density of states at Landau level.

44. Calculate diamagnetic response of free electrons. Explain why diamagnetism of free electrons is essentially quantum effect.

45. What is the reason for magnetization oscillations? What is the period of the oscillations?

46. Discuss Boltzmann equation. What is the collision term for scattering by impurities? What is the relaxation time approximation?

47. What is residual resistance? Derive Drude formula for dc conductivity.

48. Derive conductivity in ac electric field. What is the difference between low and high frequency conductivity?

49. Derive thermal conductivity. What causes deviations from Wiedemann-Franz law?

50. Why semiclassical approximation is good for kinetics of the Fermi electrons?

51. Calculate thermoelectric power.

52. Calculate Joule losses in time-dependent electric field.

53. Derive conductivity tensor for electrons in magnetic field. Calculate Hall constant.