

Example Questions for an Oral Exam for CMP major:

1. Two particles have finite spin: one is a spin-1, the other spin-1/2. What are the possible total spins of these two particles? How many spin angular momentum states could the two-particle system have? If we have three spin-1/2 particles, how many spin angular momentum states can we have? How is this case different from the previous one?
2. An electron has an intrinsic angular momentum called spin, and an associated magnetic moment. Attempt was made to explain this phenomenon classically when it was first discovered. How would you try to relate these two quantities (angular momentum and magnetic moment) classically? Would this relationship be related to how fast the electron spins around its axis?
3. In solids, there are metals and insulators. Their resistance differs by many orders of magnitude. If you attempt to explain the resistance by the scattering experienced by traveling electrons, the change of the resistance would be more gradual but it is not. Why is it so?
4. Hydrogen Atom – 3D: Potential function; Expression for Eigen value; If an electric field is applied along z-direction (Stark Effect) to a hydrogen atom, how will you approach the calculation of the ground state energy?
5. Consider a simple example of a 1-d protein with N equidistant nodes embedded in a 2-d box of infinite size. If the folding can be represented by a self-avoiding random walk, how should the overall 2-d size of the protein (RMS of the node positions) grow as N is increased?
6. Write down Landau's mean field free energy equation of phase transition. What is the equilibrium condition? Sketch the free energy for a first order phase transition.
7. (specialty) Consider the Kronig-Penny 1-d model of a lattice, consisting of delta-function potentials separated by lattice spacing a , with periodic boundary conditions. Qualitatively explain how a band gap can form.
8. (specialty) Can you explain why graphene (or some carbon nanotubes) can be metallic while the diamond is an insulator, in terms of types of electronic bonding?
9. (specialty) Non-interacting (classical) magnetic dipoles can orient themselves to an external magnetic field. The Pauli exclusion principle prevents the non-interacting Fermi gas from full magnetic polarization. Explain the mechanism that leads to the partial polarization of degenerate Fermi gas in terms of the competition between the Zeeman and kinetic energy of electrons.
10. (specialty) Why are semiconductors so versatile?
11. (very specialized) What is the origin of the pairing mechanism in conventional superconductors?
12. (specialty) Give some examples of collective modes in condensed matter physics.
13. (specialty) Say a few things about topological materials.