Fall 2004 – Entrance Examination: Condensed Matter
Multiple choice quizzes

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1. Suppose to be able to measure the metallic conductance of a piece of metal, no matter how small its size and number of atoms N could be. Below a certain number N, one could expect that:

   (A) energy levels accumulate, and metallic conduction will be lost.

   (B) energy levels rarefy, and metallic conduction will be lost.

   (C) energy levels rarefy, but metallic conduction is enhanced by lack of scattering.

   (D) energy levels accumulate, and metallic conduction is enhanced, as in a superconductor.

2. In a classical physical system whose dynamics is *chaotic*

   (A) a small change in initial conditions has no effect

   (B) a small change in initial conditions has an effect that decreases exponentially with time

   (C) a small change in initial conditions has an effect that increases exponentially with time

   (D) a small change in initial conditions cannot be applied

3. A piece of dry wood is a reasonably good electrical insulator, because:

   (A) the electronic states of cellulose near the Fermi level are scarce and localized.

   (B) the structure of molecules in wood is disordered, and very far from the crystalline structure typical of metals.

   (C) the well aligned cellulose fibers of wood do not allow three-dimensional conduction.

   (D) the phononic states of the wooden matrix and of cellulose are localized, and impede the motion of free electrons, even if abundant near the Fermi level.

4. A system consisting of two hydrogen atoms artificially mantained at some large but finite distance, is in its electronic ground state. A mearurement revealing the spin state of the electrons on the two hydrogens will find that:

   (A) the two spins are parallel

   (B) the two spins are zero

   (C) each spin is compensated by the orbital moment

   (D) the two spins are antiparallel

5. Two helium atoms are far apart in space at a distance D. Calling E_0 the electronic energy of each atom (considering the nucleus to be classical), the total energy of the system will be $2E_0 + \Delta(D)$, where Δ is due to a very weak interaction energy between the atoms. As D increases, $\Delta(D)$ will be:

   (A) negative, and exponentially decreasing.

   (B) positive, and exponentially decreasing.

   (C) positive, and decreasing as a power.

   (D) negative, and decreasing as a power.

6. The dissociation energies of H_2, HD and D_2 are different due to the zero point motion and are: (Choose the line with the correct energies)

   (A) 4.477 eV (D_2), 4.513 eV (HD), and 4.556 eV (H_2).

   (B) 4.477 eV (HD), 4.513 eV (H_2), and 4.556 eV (D_2).

   (C) 4.477 eV (H_2), 4.513 eV (HD), and 4.556 eV (D_2).

   (D) 4.477 eV (H_2), 4.513 eV (D_2), and 4.556 eV (HD).

7. The boron atom has one electron in the $2p$ shell. Therefore, in a Stern-Gerlach apparatus, a beam of boron atoms, assumed to be in their ground state, should split into several beams. How many? Answer accounting for the spin angular momentum (the sign of spin orbit is such that the lowest j is lowest in energy) or assuming that there is no spin.

   (A) 2 (with spin) and 1 (no spin)

   (B) 2 (with spin) and 3 (no spin)

   (C) 4 (with spin) and 1 (no spin)

   (D) 4 (with spin) and 3 (no spin)

8. Consider the effect of isotopic mass on the vibrational frequency of HCl molecule. What is the ratio between the stretching frequency of the deuterated molecule DCl and that of HCl molecules (the mass of Cl is $35m_H$, the mass of D is $2m_H$)?

   (A) 0.717

   (B) 0.986 = $\sqrt{36/37}$

   (C) 1.014 = $\sqrt{37/36}$

   (D) 2.000

9. A one-dimensional Heisenberg quantum ferromagnet is:

   (A) ordered below a finite Curie temperature;

   (B) ordered only at zero temperature;

   (C) always disordered because of Mermin-Wagner theorem;

   (D) ordered at any temperature.

10. The conductivity of a metallic sample is finite at zero temperature because:

(A) there are umklapp processes;

(B) the electrons are scattered by the lattice;

(C) the electrons interact;

(D) there are always impurities.

11. A free electron with finite kinetic energy impinges on a potential well:

(A) it will be partially transmitted and partially reflected back;

(B) it will be always totally transmitted;

(C) it will be always totally reflected;

(D) it will be trapped inside the potential well.

12. The magnetic susceptibility of the conduction electrons:

(A) Has only a paramagnetic contribution.

(B) Has only a diamagnetic contribution.

(C) Has both paramagnetic and diamagnetic contributions.

(D) Is divergent at any temperature and only the coupling with the ions makes the susceptibility of a metal finite.

13. At low temperature aluminum is a superconductor with $T_c \sim 1.2K$. The electronic specific heat below T_c:

(A) Is zero, because of the Meissner effect.

(B) Decreases exponentially with the temperature, due to the presence of a gap in the excitation spectrum.

(C) Goes to zero linearly with the temperature, because of the unpaired electrons.

(D) Goes to a constant, due to the effect of the impurities, always present in a solid.

14. Well above the Debye temperature, the crystal contribution to the specific heat:

(A) Increases linearly with the temperature.

(B) Decreases exponentially to zero.

(C) Tends to a constant value.

(D) Oscillates around the Dulong-Petit value.

15. Consider a gas of electrons (with a positive-charged background), in the high density limit:

(A) The kinetic energy is larger than the potential (electron-electron) one.

(B) The potential energy is larger than the kinetic one.

(C) Both contributions are of the same order.

(D) The system cannot be stable and phase separates.