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# Fall 2006 - Entrance Examination: Condensed Matter
## Multiple choice quizzes

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1. At a first order phase transition:

   A. The free energy is continuous and differentiable, the internal energy and the entropy are only continuous.

   B. The free energy is continuous but not differentiable, the internal energy and the entropy have a jump.

   C. The free energy has a jump, the internal energy and the entropy have a Dirac $\delta$ contribution.

   D. The free energy, the internal energy and the entropy all have a Dirac $\delta$ contribution.

2. Among simple quantum systems, some possess a zero-point kinetic energy in their ground state, and some don't. Consider two examples, a linear harmonic oscillator, and a planar rotor.

   A. Both possess zero-point energy

   B. The rotor has zero-point energy, the oscillator not

   C. The oscillator has zero-point energy, the rotor not

   D. Neither of them has zero-point energy

3. At extremely large pressures all matter turns into a metallic electron fluid neutralized by positive ion cores. In this limit the total energy will be dominated by

   A. The ion-ion and the electron-electron coulomb repulsion

   B. The ion-electron attraction

   C. The electron-electron exchange attraction

   D. The electron kinetic energy

4. A rare gas atom adsorbs through weak van der Waals forces on the surface of a given insulating material. The material is subsequently driven, by some external means, from insulating to metallic, with a slight increase of electron density but no other change. What will happen to the adatom?

   A. It will become slightly more bound, as van der Waals forces become a little more attractive at the insulator-metal transition.

   B. It will be ejected, as van der Waals forces turn from weakly attractive to weakly repulsive at the insulator-metal transition.

C. It will be sucked into the metal, whose free electrons can now make a chemical bond with the adatom.

D. Nothing at all

5. When a magnetic field is applied to a free electron system the up and down spin electrons acquire a Zeeman splitting,leading to a kinetic energy decrease proportional to $B^2$. On top of that, the electron kinetic energies also suffer a separate increase, due to orbital motion, also proportional to $B^2$, but independent of spin.

   A. True, this is in fact the Landau diamagnetism

   B. True,this is in fact the Van Vleck paramagnetism

   C. True, this is in fact the Pauli paramagnetism

   D. False, there is no such spin independent term. The magnetic properties of electrons are entirely due to spin.

6. When electrons oscillate in a solid, they give rise to plasmons – excitations whose frequency squared is in the long wavelength limit ($k \longrightarrow 0$) just proportional to the electron density, and inversely proportional to their mass. When ions oscillate in a solid, they should therefore give rise to a similar excitation, of much lower frequency because of their heavy mass, but still finite for $k \longrightarrow 0$. However experimentally there is no such ionic plasmon.

   A. False, ionic plasmons do exist, only their cross section is too small to be measured.

   B. The ionic plasmon does not exist because the ions are classical. Plasmons only exist for electrons that are quantum.

   C. The ion plasma mode in reality exists, but is pushed to infinite frequency by the singular nature of Coulomb forces, $4\pi/k^2$, as $k \longrightarrow 0$.

   D. The ion plasma mode in reality exists, but is pushed to zero frequency by electron screening, which transforms it into the acoustic phonon.

7. Ice floats on water. This indicates that:

   A. The entropy of liquid water is lower than the entropy of ice.

   B. The ice melting temperature decreases with pressure.

   C. The ice melting temperature increases with pressure.

   D. The entropy of ice decreases with increasing temperature

8. According to the Boltzmann law, the probability distribution for the values of the magnetic moment ($M$) of a finite sample of a materials is invariant with respect to inversion ($M \rightarrow -M$). In the absence of an applied magnetic field (B=0), this implies that:

   A. The equilibrium value of $M$ is zero, and ferromagnetism is due to the finite value of the Earth magnetic field.

B. The equilibrium value of $M$ is zero only for highly symmetric samples. Ferromagnetism is due to surface effects which may break the magnetization-inversion symmetry.

C. The equilibrium value of $M$ is zero, and ferromagnetism is actually an out-of-equilibrium phenomenon, where the direction of the magnetization fluctuates on a time scale that diverges with the size of the system.

D. None of the above. the equilibrium value of $M$ may be different from zero because thermal fluctuations destroy the magnetization-inversion symmetry.

9. Methanol ($CH_3OH$) is liquid at standard T and P conditions while Methane ($CH_4$) and Oxygen ($O_2$) are in the gas phase. Consider a process converting $CH_4$ + 1/2 $O_2$ into methanol at ambient pressure and temperature. What do you expect would be the effect of pressure on the process ?

   A. Raising the pressure the conversion will be enhanced.

   B. Raising the pressure the conversion will be hindered.

   C. No marked effect. More details are needed to decide.

   D. Only changing the temperature one can modify the reaction rate.

10. Which one of the following Maxwell equations is wrong ?

    A. $\nabla \cdot \mathbf{D} = 4\pi\rho$

    B. $\nabla \times \mathbf{E} + \frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} = 0$

    C. $\nabla \cdot \mathbf{B} = \frac{4\pi}{c}\mathbf{j}$

    D. $\nabla \times \mathbf{H} - \frac{1}{c}\frac{\partial \mathbf{D}}{\partial t} = \frac{4\pi}{c}\mathbf{j}$

11. A classical charged particle sits at distance $d$ form a flat metallic surface. How much energy is needed to remove the particle ti infinite distance ?

    A. $Q^2/d$

    B. $Q^2/2d$

    C. $Q^2/4d$

    D. It depends on the work function of the metal.

12. The dissociation energy of Deuterium molecule $D_2$ molecule is:

    A. Much smaller than that of $H_2$.

    B. Slightly larger than that of $H_2$.

    C. Slightly smaller than that of $H_2$.

    D. Equal to that of $H_2$.

13. A good fraction of isolated atoms has a magnetic ground state, but magnetism is far less frequent in simple molecules. Why ?

A. It costs too much energy to sustain a magnetic field in a larger portion of space.

B. Spin-orbit coupling is far less important, and it destroy magnetism.

C. The inter-atomic electrostatic interactions tend to suppress the exchange interactions which are responsible for magnetism.

D. Electrons are more often unpaired in an atom than in a molecule.

14. In thermal equilibrium any system

A. is usually found in its ground state.

B. is more likely to be in the ground state than in any other single state.

C. is more likely to have an energy near the ground state that near any other one.

D. is equally likely to be in any state.