SCUOLA INTERNAZIONALE
SUPERIORE di STUDI AVANZATI
International School
for Advanced Studies
via Bonomea 265 • 34136 Trieste • ITALY
T +39 040 3787 111 • F +39 040 3787 249
www.sissa.it

March 2013 - Entrance Examination: Condensed Matter
Multiple choice quizzes

1. Among the most common elemental solids, chromium, manganese, iron, cobalt, nickel stand out for being ferro or antiferromagnetic, whereas the others are not. Why?

   A. Because these are metals, the others insulators. In metals there are spontaneous currents that produce magnetism.

   B. Because they have partly filled d-orbitals that support intra-atomic, internal orbital currents, leading to magnetism.

   C. Because their atoms have partly filled d-orbitals that permit a lower electron repulsion when their spins are parallel; these atomic spins then line up below the Curie or Neel temperature, giving rise to magnetism.

   D. Because the nuclei of chromium, manganese, iron, cobalt, nickel, unlike all others, possess nuclear spins; these spins then line up below the Curie or Neel temperature, giving rise to magnetism.

2. To a first approximation the two electrons in a helium atom occupy the same 1s orbital with opposite spins. (Call E_0 the energy expectation value in that approximate state). In the exact ground state however:

   A. due to correlations there is a small probability for the two 1s spins to be parallel, and this lowers the energy below E_0.

   B. due to correlations, the two electrons are able to avoid each other more effectively, and this lowers the energy below E_0.

   C. electrostatic repulsion of the two electrons introduces a small positive correction, which raises the energy slightly above E_0.

   D. the first Hund's rule applies, and the configuration switches to parallel 1s electrons with total spin 1, with energy slightly below E_0.

3. Consider the simple ionization process:

$$h\nu + \text{He} \longrightarrow \text{He}^+ + \text{e}^-,$$

where the Helium atom is initially in its ground state (whose total energy is $E = -78.88$ eV) and the He^+ ion in the final state is also in its ground state. What is the minimum energy that the incoming photon must have in order to ionize the system?

   A. 24.46 eV
   B. 51.66 eV
   C. 65.27 eV
   D. 78.88 eV

4. An electron in a rigid box with hard walls may be seen as exerting a pressure on the walls. In classical mechanics, that pressure exists and is due to temperature, that drives frequent collisions of the electron with the walls. In quantum mechanics, and at zero temperature:

   A. the pressure becomes negative, as the electron falls in a bound state with the walls
   B. the pressure vanishes as there are no more collisions
   C. the pressure is equal to $\hbar$.
   D. the pressure is positive, the electron kinetic energy decreasing with increasing volume;

5. The Co atom has a ground state electronic configuration $1s^2 2s^2 2p^6 3d^7 4s^2$. According to Hund's rules its ground state is: (we indicate each term with the symbol $^{2S+1}L_J$ where S is the total spin angular momentum, L the total orbital angular momentum and J the total angular momentum)

   A. $^4F_{9/2}$.
   B. $^2F_{7/2}$.
   C. $^1S_0$.
   D. $^4F_{3/2}$.

6. In a semiconductor the current can be due to electrons or holes depending on doping. The two currents can be distinguished because:

   A. In an applied electric field they have opposite directions.
   B. The electric field generated by the Hall effect has opposite polarity in the two cases.

C. It is not possible to distinguish the two currents by macroscopic measurements.

D. Hole currents do not exist, only electrons move.

7. The ground state electronic configuration of the Carbon atom is $1s^2 2s^2 2p^2$. This configuration is 15-fold degenerate and these levels are split by the residual Coulomb interaction into the terms ${}^1S$, ${}^3P$ and ${}^1D$. An excited state electronic configuration is $1s^2 2s 2p^3$. Which is the degeneracy of this configuration?

   A. 20.

   B. 30.

   C. 40.

   D. 1.

8. A classical harmonic oscillator in one dimension is described by the equation $\frac{d^2x}{dt^2} = -\omega_0^2 x$. In presence of friction the motion is described by the equation $\frac{d^2x}{dt^2} = -\omega_0^2 x - \gamma \frac{dx}{dt}$. Suppose γ sufficiently small that the motion remain oscillatory with decreasing amplitude and call ω_1 the angular frequency of oscillation. Which one of the following hold?

   A. $\omega_1 = \omega_0$.

   B. $\omega_1 < \omega_0$.

   C. $\omega_1 > \omega_0$.

   D. $\omega_1 = \omega_0 + \gamma$

9. Let us consider a planar molecule formed by four equal atoms at the vertexes of a square. How many vibrational modes of non zero frequency have displacements in the plane and how many perpendicular to the plane?

   A. 5 in the plane and 1 perpendicular.

   B. 4 in the plane and 2 perpendicular.

   C. 3 in the plane and 3 perpendicular.

   D. 2 in the plane and 4 perpendicular.

10. Let us call **a**, **b**, and **c** the three primitive vectors of a simple monoclinic Bravais lattice. Suppose that the angle between **a** and **b** is different from 90°, while **a** and **c** as well as **b** and **c** are perpendicular. The lattice is symmetric with respect to a two-fold rotation about an axis which is:

   A. Parallel to **a**.

   B. Parallel to **b**.

C. Parallel to **c**.

D. There is no two-fold rotational axis, there is only a mirror symmetry.

11. The muon is a particle with the same charge and spin as the electron but a mass about 200 times larger. Suppose that an atom is formed by muons that move around a nucleus of positive charge Z. With respect to the corresponding electron atom with the same Z, in the muon atom:

    A. The atomic radius is about 200 times larger.

    B. The atomic radius is about 200 smaller.

    C. The ionization potential is about 200 times smaller.

    D. The shell structure is completely different.

12. A cyclotron shoots protons of 1 MeV kinetic energy against an Aluminum ($Z = 13$) target. What is the closest distance from the Aluminum nuclei the protons can reach? (Hint: Recall that $e^2/a_{Bohr} \approx 27.2eV$.)

    A. $\approx 2 \times 10^{-10}$ m

    B. $\approx 2 \times 10^{-12}$ m

    C. $\approx 2 \times 10^{-14}$ m

    D. $\approx 2 \times 10^{-16}$ m