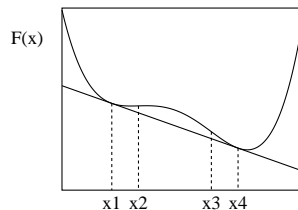


- 1 The ground-state wave-function of a particle moving in 1D under the influence of a local potential, $V(x)$, has the following asymptotic form: $\psi(x) \sim c \times \exp(-\alpha x^4)$, for $x \rightarrow \infty$. What is the large- x asymptotic behaviour of the potential?
 - A. $V(x) \sim \text{constant}$
 - B. $V(x) \sim x^4$
 - C. $V(x) \sim x^6$
 - D. None of the above.
- 2 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. $\nabla \times \mathbf{H} - \frac{1}{c} \frac{\partial \mathbf{D}}{\partial t} = \frac{4\pi}{c} \mathbf{j}$
- 3 A free particle is confined into a finite 1D box. The discrete energy levels depend on the quantum number n as:
 - A. $E_n \sim n$
 - B. $E_n \sim \sqrt{n}$
 - C. $E_n \sim n^2$
 - D. None of the above.
- 4 Neglecting the electron-electron interaction, an excited state of the Helium atom has quantum numbers: $l_1 = 2$ and $l_2 = 3$, where l_i is the angular momentum of one of the two electrons. Say which of the following values of the *total* angular momentum, L , and parity, I are compatible with these data.
 - A. $L = 0$; $I = -1$
 - B. $L = 1$; $I = -1$
 - C. $L = 1$; $I = 1$
 - D. The problem is ill-defined for, because of the Pauli principle, one cannot associate any well defined angular momentum to each electron.
- 5 The surface of a sphere of radius R is uniformly charged and the integrated charge is independent of R . The electrostatic pressure acting on the surface depends on R as:
 - A. $P(R) \sim 1/R^4$
 - B. $P(R) \sim 1/R^2$
 - C. $P(R) \sim 1/R$
 - D. $P(R) \sim \text{const}$
- 6 The approximate calculation of the free energy of the mixture of two liquids A and B , $A_x B_{1-x}$, as a function of the molar fraction, x , and at constant temperature gave the following result:



Which one of the following statements is correct?

- A. The homogeneous mixture of the two liquids is only stable for $x < x_1$ or $x > x_4$.
- B. The homogeneous mixture of the two liquids is only stable for $x < x_2$ or $x > x_3$.
- C. A homogeneous mixture of the two liquids cannot exist in the ranges $x_1 < x < x_2$ or $x_3 < x < x_4$.
- D. The homogeneous mixture is stable for all the values of the molar fraction, x .

- 7 A classical charged particle sit at distance d from a flat metallic surface. How much energy is needed to remove the particle to infinite distance?
- Q^2/d
 - $Q^2/2d$
 - $Q^2/4d$
 - It depends of the work function of the metal.
- 8 Suppose that a given material can be produced while monitoring the isotopic composition of its atoms and let M be the average mass of the atoms. What is the dependence of the sound velocity of that material, c , upon M ?
- c is independent of M .
 - $c \propto M$.
 - $c \propto \sqrt{M}$.
 - $c \propto 1/\sqrt{M}$.
- 9 The density of materials usually decreases upon increasing temperature. This fact indicates that:
- The harmonic approximation is inadequate to describe lattice vibrations.
 - The independent-electron approximation is not valid.
 - The continuum elasticity model for sound propagation breaks down.
 - The thermal excitations of the electrons have to be taken into account.
- 10 Consider the collisions between molecules in a dilute gas in equilibrium at room temperature. If n is the number of molecules per unit volume and σ is the total cross section of a molecule, what is the order of magnitude of the mean free path, i.e. the average distance between two successive collisions of a molecule?
- $(n\sigma)^{-1}$
 - $\sigma^{1/2}$
 - $n^{-1/3}$
 - 1 Å.
- 11 The Fermi energy of a free-electron metal increases, with decreasing volume, as
- V^{-1}
 - $V^{-1/2}$
 - $V^{-2/3}$
 - None of the above.
- 12 The dissociation energy of the $^2\text{H}_2$ molecule (the superscript indicate the isotopic number) is:
- Much smaller than that of $^1\text{H}_2$.
 - Slightly larger than that of $^1\text{H}_2$.
 - Slightly smaller than that of $^1\text{H}_2$.
 - Equal to that of $^1\text{H}_2$.
- 13 The linear dimensions of an ink drop, dropped in otherwise clean water, are observed to increase in time proportionally to $t^{1/2}$. This fact indicate that:
- The ink molecule strongly repel each other.
 - The ink molecules slightly attract each other.
 - The polar water molecules mediate a weak repulsive interaction among the ink molecules which would not otherwise interact in vacuum.
 - The interaction among the ink molecules is negligible, and the motion is purely diffusive.
- 14 Consider an H_2 molecule and imagine to increase adiabatically the proton-proton distance. In the large-distance limit.
- The bond will break and the two atoms will repel each other because of the residual overlap between the atomic orbitals.
 - The two atoms will continue to attract each other, but the strength of the bond will decrease exponentially, due to the exponential decay of the electronic charge distribution of the two atoms.

- C. Because the H negative ion is stable, the two product atoms will be ionised with opposite charge and will attract each other with a Coulomb interaction.
 - D. The two atoms will attract each other with an interaction which decrease with a power law as function of the inter-atomic separation, and which is due to correlation effects that cannot be accounted for in the Hartree-Fock interaction.
- 15** 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 destroys magnetism.
 - C. Electrons are more often unpaired in an atom than in a molecule.
 - D. The inter-atomic electrostatic interactions tend to suppress the exchange interactions which are responsible for magnetism.
- 16** A monoatomic ideal gas confined onto a 2-dimensional substrate has a specific heat per mole which is (R = gas constant):
- A. $\frac{3}{2}R$.
 - B. R .
 - C. $R \times \left(\frac{T}{T_{Debye}}\right)^2$.
 - D. $R \times \frac{T}{T_{Fermi}}$.

Questions 17-18 should be answered only by candidates interested in the bio-simulation curriculum

- 17** What kind of interactions take place between the DNA nucleobases?
- A. Hydrophobic interactions.
 - B. Electrostatic interactions.
 - C. H-bond interactions.
 - D. Salt bridges.
- 18** What is the secondary structure of proteins?
- A. The arrangement in space of all the atoms.
 - B. The arrangement in space of the backbone atoms.
 - C. The order in which aminoacids are linked by peptide bonds.
 - D. The interaction between subunits.
- 19** What is the biological function of enzymes?
- A. Catalysis.
 - B. Electron transfer.
 - C. Oxygen storage.
 - D. None of the above.
- 20** Which of the following nucleobases is not present in DNA?
- A. Adenine.
 - B. Thymine.
 - C. Uracil.
 - D. Guanine.