GATE (2020) PH(14-26)

EE24BTECH11040 - Mandara Hosur

Each of the following questions carry one mark each

1) Let $\hat{a}$ and $\hat{a}^\dagger$, respectively denote the lowering and raising operators of a one-dimensional simple harmonic oscillator. Let $|n\rangle$ be the energy eigenstate of the simple harmonic oscillator. Given that $|n\rangle$ is also an eigenstate of $\hat{a}^\dagger\hat{a}^\dagger\hat{a}\hat{a}$, the corresponding eigenvalue is
   a) $n(n-1)$
   b) $n(n+1)$
   c) $(n+1)^2$
   d) n^2

2) Which one of the following is a universal logic gate?
   a) AND
   b) NOT
   c) OR
   d) NAND

3) Which one of the following is the correct binary equivalent of the hexadecimal F6C?
   a) 0110 1111 1100
   b) 1111 0110 1100
   c) 1100 0110 1111
   d) 0110 1100 0111

4) The total angular momentum j of the ground state of the ${}^{17}_{8}O$ nucleus is
   a) $\frac{1}{2}$
   b) 1
   c) $\frac{3}{2}$
   d) $\frac{5}{2}$

5) A particle X is produced in the process $\pi^+ + p \rightarrow K^+ + X$ via the strong interaction. If the quark content of the K^+ is $u\bar{s}$, the quark content of X is
   a) $c\bar{s}$
   b) uud
   c) uus
   d) $u\bar{d}$

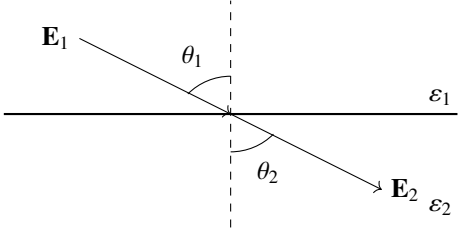
6) A medium ($\varepsilon_r > 1$, $\mu_r = 1$, $\sigma > 0$) is semi-transparent to an electromagnetic wave when
   a) Conduction current >> Displacement current
   b) Conduction current << Displacement current
   c) Conduction current = Displacement current
   d) Both Conduction current and Displacement current are zero

7) A particle is moving in a central force field given by $\mathbf{F} = -\frac{k}{r^3}\hat{\mathbf{r}}$ where $\hat{\mathbf{r}}$ is the unit vector pointing away from the center of the field. The potential energy of the particle is given by
   a) $\frac{k}{r^2}$
   b) $\frac{k}{2r^2}$
   c) $-\frac{k}{r^2}$
   d) $-\frac{k}{2r^2}$

8) Choose the correct statement related to the Fermi energy (E_F) and the chemical potential (μ) of a metal.
   a) $\mu = E_F$ only at 0 K
   b) $\mu = E_F$ at finite temperature
   c) $\mu < E_F$ at 0 K
   d) $\mu > E_F$ at finite temperature

9) Consider a diatomic molecule formed by identical atoms. If E_V and E_e represent the energy of the vibrational nuclear motion and electronic motion respectively, then in terms of the electronic mass m and nuclear mass M, $\frac{E_V}{E_e}$ is proportional to
   a) $\left(\frac{m}{M}\right)^{\frac{1}{2}}$
   b) $\frac{m}{M}$
   c) $\left(\frac{m}{M}\right)^{\frac{3}{2}}$
   d) $\left(\frac{m}{M}\right)^{2}$

10) Which one of the following relations determines the manner in which the electric field lines are refracted across the interface between two dielectric media having dielectric constants ε_1 and ε_2 (see figure)?



   a) $\varepsilon_1 \sin\theta_1 = \varepsilon_2 \sin\theta_2$
   b) $\varepsilon_1 \cos\theta_1 = \varepsilon_2 \cos\theta_2$
   c) $\varepsilon_1 \tan\theta_1 = \varepsilon_2 \tan\theta_2$
   d) $\varepsilon_1 \cot\theta_1 = \varepsilon_2 \cot\theta_2$

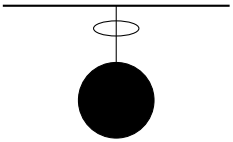
11) If $\mathbf{E}$ and $\mathbf{B}$ are the electric and magnetic fields respectively, then $\mathbf{E} \cdot \mathbf{B}$ is
   a) odd under parity and even under time reversal
   b) even under parity and odd under time reversal
   c) odd under parity and odd under time reversal
   d) even under parity and even under time reversal

12) A small disc is suspended by a fiber such that it is free to rotate about the fiber axis

(see figure). For small angular deflections, the Hamiltonian for the disc is given by

$$H = \frac{p_\theta^2}{2I} + \frac{1}{2}\alpha\theta^2$$

where I is the moment of inertia and α is the restoring torque per unit deflection. The disc is subjected to angular deflections (θ) due to thermal collisions from the surrounding gas at temperature T and p_θ is the momentum conjugate to θ. The average and the root-mean-square angular deflection, θ_{avg} and θ_{rms}, respectively are



a) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{\frac{3}{2}}$

b) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{\frac{1}{2}}$

c) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{\frac{1}{2}}$

d) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{\frac{3}{2}}$

13) As shown in the figure, an ideal gas is confined to chamber A of an insulated container, with vacuum in chamber B. When the plug in the wall separating the chambers A and B is removed, the gas fills both the chambers. Which one of the following statements is true?

a) The temperature of the gas remains unchanged

b) Internal energy of the gas decreases

c) Temperature of the gas decreases as it expands to fill the space in chamber B

d) Internal energy of the gas increases as its atoms have more space to move around