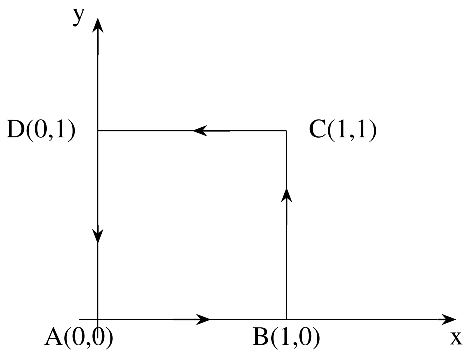
2024-PH- 40-52

EE24BTECH11016 - DHWANITH M DODDAHUNDI

40) In a parallel plate capacitor, the plate at $x = 0$ is grounded and the plate at $x = d$ is maintained at a potential V_0 . The space between the two plates is filled with a linear dielectric of permittivity $\epsilon = \epsilon_0 \left(1 + \frac{x}{d}\right)$, where ϵ_0 is the permittivity of free space. Neglecting the edge effects, the electric field $(\vec{E})$ inside the capacitor is
    a) $-\frac{V_0}{(d+x)ln2}\hat{x}$
    b) $-\frac{V_0}{d}\hat{x}$
    c) $-\frac{V_0}{(d+x)}\hat{x}$
    d) $-\frac{V_0 d}{(d+x)x}\hat{x}$
41) The equation of motion for the forced simple harmonic oscillator is
    $\ddot{x}(t) + \omega^2 x(t) = F\cos(\omega t)$
    where $x(t = 0) = 0$ and $\dot{x}(t = 0) = 0$. Which one of the following options is correct?
    a) $x(t) \propto t\sin(\omega t)$
    b) $x(t) \propto t\cos(\omega t)$
    c) $x(t) = \infty$
    d) $x(t) \propto e^{\omega t}$
42) An atom is subjected to a weak uniform magnetic field $\vec{B}$. The number of lines in its Zeeman spectrum for transition from $n = 2, l = 1$ to $n = 1, l = 0$ is
    a) 8
    b) 10
    c) 12
    d) 5
43) Consider two matrices: P=$\begin{pmatrix} 1 & 2 \\ 0 & 1 \end{pmatrix}$ and Q=$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
    Which of the following statement is/are true?
    a) P and Q have same set of eigenvalues
    b) P and Q commute with each other
    c) P and Q have different sets of linearly independent eigenvectors
    d) P is diagonalizable
44) An infinite one dimensional lattice extends along x-axis. At each lattice site there exists an ion with spin $\frac{1}{2}$. The spin can point either in +z or -z direction only. Let S_P, S_F, and S_A denote the entropies of paramagnetic, ferromagnetic and antiferromagnetic configurations, respectively. Which of the following relation is/are true?
    a) $S_P > S_F$
    b) $S_A > S_F$
    c) $S_A = 4S_F$
    d) $S_P > S_A$

45) Cosider a vector field $\overrightarrow{F} = (2xz + 3y^2)\hat{y} + 4yz^2\hat{z}$. The closed path $(\Gamma : A \to B \to C \to D \to A)$ in $z = 0$ plane is shown in figure.



$\oint_\Gamma \overrightarrow{F}.\overrightarrow{dl}$ denotes the line integral of $\overrightarrow{F}$ along the closed path Γ. Which of the following option is/are true?

a) $\oint_\Gamma \overrightarrow{F} \cdot \overrightarrow{dl} = 0$
b) $\overrightarrow{F}$ is non-conservative
c) $\overrightarrow{\nabla} \cdot \overrightarrow{F} = 0$
d) $\overrightarrow{F}$ can be written as the gradient of a scalar field

46) Two point charges of charge $+q$ each are placed a distance $2d$ apart. A grounded solid conducting sphere of radius a is placed midway between them. Assume $a^2 << d^2$. Which of the following statement is/are true?

a) If $a > \frac{d}{8}$ the net force acting on the charges is directed towards each other
b) The potential at the surface of the sphere is zero
c) Total induced charge on the sphere is $\left(-\frac{2aq}{d}\right)$
d) The potential at the center of the sphere is non-zero

47) A particle of mass m is moving in the potential

$$V(x) = \begin{cases} V_0 + \frac{1}{2}m\omega_0^2 x^2 & x > 0 \\ \infty & x \leq 0 \end{cases}$$

Figures P, Q, R and S show different combinations of the values of ω_0 and V_0 .

Figure P

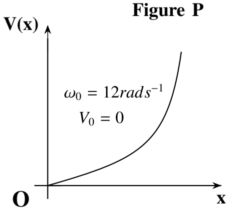


Figure Q

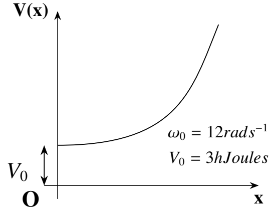


Figure R

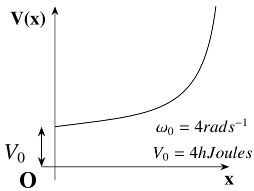
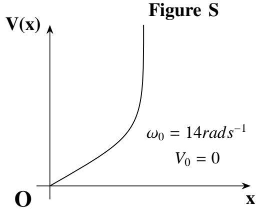


Figure S



$E_j^{(P)}, E_j^{(Q)}, E_j^{(R)}$ and $E_j^{(S)}$ with $j = 0, 1, 2, \cdots$ are the eigen-energies of the j-th level for the potentials shown in figures P, Q, R and S, respectively. Which of the statement is/are true?

a) $E_0^{(P)} = E_0^{(Q)}$
b) $E_0^{(Q)} = E_0^{(S)}$
c) $E_0^{(P)} = E_0^{(R)}$
d) $E_0^{(R)} \neq E_0^{(Q)}$

48) The non-relativistic Hamiltonian for a single electron atom is

$$H_0 = \frac{p^2}{2m} - V(r)$$

where $V(r)$ is the Coulomb potential and m is the mass of the electron. Considering the spin-orbit interaction term

$$H' = \frac{1}{2m^2c^2}\frac{1}{r}\frac{dV}{dr}\overrightarrow{L}\cdot\overrightarrow{S}$$

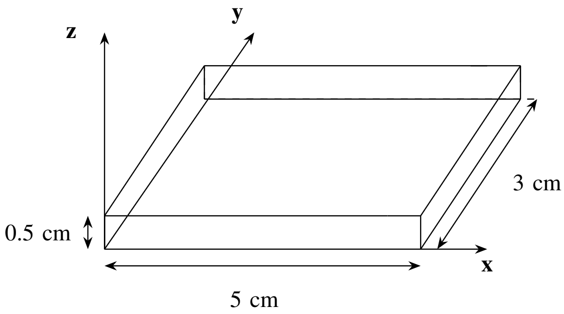
added to H_0 , which of the following statement is/are true?

a) H' commutes with L^2
b) H' commutes with L_z and S_z
c) For a given value of principal quantum number n and orbital angular momentum quantum number l, there are $2(2l+1)$ degenerate eigenstates of H_0
d) H_0, L^2, S^2, L_z and S_z have a set of simultaneous eigenstates

49) Decays of mesons and baryons can be categorized as weak, strong and electromagnetic decays depending upon the interactions involved in the processes. Which of the following option is/are true?

a) $\pi^0 \to \gamma\gamma$ is a weak decay
b) $\Lambda^0 \to \pi^0 + p$ is an electromagnetic decay
c) $K^0 \to \pi^+ + \pi^-$ is a weak decay
d) $\nabla^{++} \to p + \pi^+$ is a strong decay

50) An extrinsic semiconductor shown in figure carries a current of $2mA$ along its length parallel to $+x$ axis



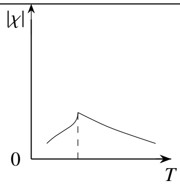
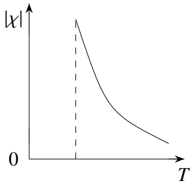
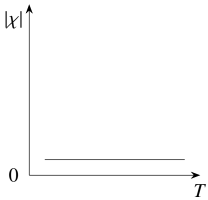
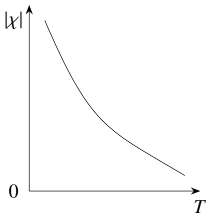
When the majority charge carrier concentration is $12.5 \times 10^{13}\ cm^{-3}$ and the sample is exposed to a constant magnetic field applied along the $+z$ direction, a Hall voltage of 20 mV is measured with the negative polarity at $y = 0$ plane. Take the electric charge as 1.6×10^{-19}C. The concentration of minority charge carrier is negligible. Which of the following statement is/are true?

a) The majority charge carrier is electron
b) The magnitude of the applied magnetic field is 1 Tesla
c) The electric field corresponding to the Hall voltage is in the $+y$ direction
d) The magnitude of Hall coefficient is 50,000 m^3C^{-1}

51) A^α and B_β $(\alpha, \beta = 1, 2, 3, \cdots, n)$ are contravariant and covariant vectors, respectively. By convention, any repeated indices are summed over. Which of the following expression is/are tensors?

a) $A^\alpha B_\beta$
b) $\frac{A^\alpha B_\beta}{A^\alpha B_\alpha}$
c) $\frac{A_\alpha}{B_\beta}$
d) $A^\alpha + B_\beta$

52) The temperature T dependence of magnetic susceptibility γ (Column I) of certain magnetic materials (Column II) are given below. Which of the following option is/are correct?

<table>
<tr><th>Column 1</th><th>Column 2</th></tr>
<tr><td>(1) </td><td>(P) Diamagnetic</td></tr>
<tr><td>(2) </td><td>(Q) Paramagnetic</td></tr>
<tr><td>(3) </td><td>(R) Ferromagnetic</td></tr>
<tr><td>(4) </td><td>(S) Antiferromagnetic</td></tr>
</table>

a) 2 - P, 4 - Q, 3 - S
b) 4 - P, 1 - Q, 2 - R
c) 4 - Q, 2 - R, 1 - S
d) 3 - P, 4 - Q, 2 - R