PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

CSIR NET Physics - Statistical Mechanics

All PYQs (2015-2025) with answer key

108 questions . Answer key included

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Q1. [Dec 2015] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2015 Dec	3.5 M

For a system of independent non interacting one-dimensional oscillators, the value of the free energy per oscillator, in the limit $T \to 0$, is

1. $\frac{1}{2}\hbar\omega$
2. $\hbar\omega$
3. $\frac{3}{2}\hbar\omega$
4. 0

Q2. [Dec 2015] . 3.5 marks

Statistical Mechanics > Ising model

CSIR NET	2015 Dec	3.5 M

The partition function of a system of N Ising spins is $Z = \lambda_1^N + \lambda_2^N$ where λ_1 and λ_2 are functions of temperature, but are independent of N. If $\lambda_1 > \lambda_2$, the free energy per spin in the limit $N \to \infty$ is

1. $-k_B T \ln\left(\frac{\lambda_1}{\lambda_2}\right)$
2. $-k_B T \ln \lambda_2$
3. $-k_B T \ln(\lambda_1 \lambda_2)$
4. $-k_B T \ln \lambda_1$

Q3. [Dec 2015] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2015 Dec	3.5 M

The Hamiltonian of a system of N non interacting spin $-\frac{1}{2}$ particles is $H = -\mu_0 B \sum_i S_i^z$, where $S_i^z = \pm 1$ are components of i^{th} spin along an external magnetic field B. At a temperature T such that $e^{\frac{\mu_0 B}{k_B T}} = 2$. the specific heat per particle is

1. $\frac{16}{25} k_B$
2. $\frac{8}{25} k_B l n 2$
3. $k_B (ln 2)^2$
4. $\frac{16}{25} k_B (\ln 2)^2$

Q4. [Dec 2015] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2015 Dec	5 M

An ensemble of non-interacting spin $-\frac{1}{2}$ particles is in contact with a heat bath at temperature T and is subjected to an external magnetic field. Each particle can be in one of the two quantum states of energies $\pm\epsilon_0$. If the mean energy per particle is $-\epsilon_0/2$, then the free energy per particle is

1. $-2\,\epsilon_0\,\frac{\ln(4/\sqrt{3})}{\ln 3}$

2. $-\epsilon_0\; l\,n(3/2)$

3. $-2\,\epsilon_0\; l\,n\,2$

4. $-\epsilon_0\,\frac{\ln 2}{\ln 3}$

Q5. [Dec 2015] . 5.0 marks
Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2015 Dec	5 M

Consider a random walker on a square lattice. At each step the walker moves to a nearest neighbour site with equal probability for each of the four sites. The walker starts at the origin and takes 3 steps. The probability that during this walk no site is visited more than one is

1. 12/27
2. 27/64
3. 3/8
4. 9/16

Q6. [June 2015] . 3.5 marks
Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2015 June	3.5 M

A system of N distinguishable particles, each of which can be in one of the two energy levels 0 and ϵ, has a total energy $n\epsilon$, where n is an integer. The entropy of the system is proportional to

1. $N \ln n$
2. $n \ln N$
3. $\ln\left(\frac{N!}{n!}\right)$
4. $\ln\left(\frac{N!}{n!(N-n)!}\right)$

Q7. [June 2015] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2015 June	3.5 M

A system of N non-interacting classical particles, each of mass m is in a two dimensional harmonic potential of the form $V(r) = \alpha(x^2 + y^2)$ where α is a positive constant. The canonical partition function of the system at temperature T is $\left(\beta = \frac{1}{k_B T}\right)$:

1. $\left[\left(\frac{\alpha}{2m}\right)^2 \frac{\pi}{\beta}\right]^N$
2. $\left(\frac{2m\pi}{\alpha\beta}\right)^{2N}$
3. $\left(\frac{\alpha\pi}{2m\beta}\right)^N$
4. $\left(\frac{2m\pi^2}{\alpha\beta^2}\right)^N$

Q8. [June 2015] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2015 June	5 M

A large number N of Brownian particles in one dimension start their diffusive motion from the origin at time $t = 0$. The diffusion coefficient is D. The number of particles crossing a point at a distance L from the origin, per unit time, depends on L and time t as

1. $\frac{N}{\sqrt{4\pi Dt}} e^{-L^2/(4Dt)}$

2. $\frac{NL}{\sqrt{4\pi Dt}} e^{-4Dt/L^2}$

3. $\frac{N}{\sqrt{16\pi Dt^3}} e^{-L^2/(4Dt)}$

4. Ne^{-4Dt/L^2}

Q9. [June 2015] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2015 June	5 M

Consider three Ising spins at the vertices of a triangle which interact with each other with a ferromagnetic Ising interaction of strength J. The partition function of the system at temperature T is given by

$$\left(\beta = \frac{1}{k_B T}\right):$$

1. $2e^{3\beta j} + 6e^{-\beta j}$
2. $2e^{-3\beta I} + 6e^{\beta J}$
3. $2e^{3\beta J} + 6e^{-3\beta J} + 3e^{\beta J} + 3e^{-\beta J}$
4. $(2\cosh \beta J)^3$

Q10. [June 2015] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2015 June	5 M

An ideal Bose gas in d-dimensions obeys the dispersion relation $\epsilon(\vec{k}) = Ak^s$, where A and s are constants. For Bose-Einstein condensation to occur, the occupancy of excited states

1. $\frac{d}{s} < \frac{1}{4}$
2. $\frac{1}{4} < \frac{d}{s} < \frac{1}{2}$
3. $\frac{d}{s} > 1$
4. $\frac{1}{2} < \frac{d}{s} < 1$

Q11. [June 2015] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2015 June	5 M

The low-energy electronic excitations in a two-dimensional sheet of graphene is given by $E(\vec{k}) = \hbar v k$, where v is the velocity of the excitations. The density of states is proportional to

1. E
2. $E^{3/2}$
3. $E^{1/2}$
4. E^2

Q12. [Dec 2016] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2016 Dec	3.5M

Consider a gas of N classical particles in a two-dimensional square box of side L. If the total energy of the gas is E, the entropy (apart from an additive constant) is

1. $Nk_B \ln\left(\frac{L^2 E}{N}\right)$

2. $Nk_B \ln\left(\frac{LE}{N}\right)$

3. $2Nk_B \ln\left(\frac{L\sqrt{E}}{N}\right)$

4. $L^2 k_B \ln\left(\frac{E}{N}\right)$

Q13. [Dec 2016] . 3.5 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2016 Dec	3.5M

Consider a continuous time random walk. If a step has taken place at time $t = 0$, the probability that the next step takes place between t and $t + dt$ is given by $btdt$, where b is a constant. What is the average time between successive steps?

1. $\sqrt{\frac{2\pi}{b}}$

2. $\sqrt{\frac{\pi}{b}}$

3. $\frac{1}{2}\sqrt{\frac{\pi}{b}}$

4. $\sqrt{\frac{\pi}{2b}}$

Q14. [Dec 2016] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2016 Dec	3.5M

The partition function of a two-level system governed by the Hamiltonian $H = \begin{bmatrix} \gamma & -\delta \\ -\delta & -\gamma \end{bmatrix}$ is

1. $2\sinh\left(\beta\sqrt{\gamma^2+\delta^2}\right)$

2. $2\cosh\left(\beta\sqrt{\gamma^2+\delta^2}\right)$

3. $\frac{1}{2}\left[\cosh\left(\beta\sqrt{\gamma^2+\delta^2}\right)+\sinh\left(\beta\sqrt{\gamma^2+\delta^2}\right)\right]$

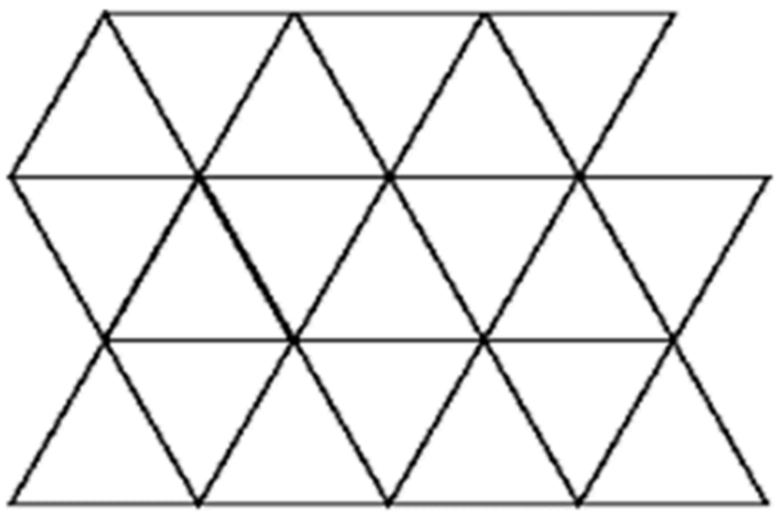
4. $\frac{1}{2}\left[\cosh\left(\beta\sqrt{\gamma^2+\delta^2}\right)-\sinh\left(\beta\sqrt{\gamma^2+\delta^2}\right)\right]$

Q15. [Dec 2016] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2016 Dec	5M

Consider a random walk on an infinite twodimensional triangular lattice, a part of which is shown in the figure below. If the probabilities of moving to any of the nearest neighbour sites are equal, what is the probability that the walker returns to the starting position at the end of exactly three steps?



1. $\frac{1}{36}$
2. $\frac{1}{216}$
3. $\frac{1}{18}$
4. $\frac{1}{12}$

Q16. [Dec 2016] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2016 Dec	5M

An atom has a non-degenerate ground-state and a doubly-degenerate excited state. The energy difference between the two states is ε. The specific heat at very low temperatures ($\beta\varepsilon \gg 1$) is given by

1. $k_B(\beta\varepsilon)$
2. $k_B e^{-\beta\varepsilon}$
3. $2k_B(\beta\varepsilon)^2 e^{-\beta\varepsilon}$
4. k_B

Q17. [Dec 2016] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2016 Dec	5M

The electrons in graphene can be thought of as a two-dimensional gas with a linear energy-momentum relation $E = |\vec{p}|v$, where $\vec{p} = (p_x, p_y)$ and v is a constant. If ρ is the number of electrons per unit area, the energy per unit area is proportional to

1. $\rho^{3/2}$
2. ρ
3. $\rho^{1/3}$
4. ρ^2

Q18. [June 2016] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2016 June	3.5M

A gas of non-relativistic classical particles in one dimension is subjected to a potential $V(x) = \alpha|x|$ (where α is a constant). The partition function is

$(\beta = \frac{1}{k_B T})$

1. $\sqrt{\frac{4m\pi}{\beta^3\alpha^2h^2}}$

2. $\sqrt{\frac{2m\pi}{\beta^3\alpha^2h^2}}$

3. $\sqrt{\frac{8m\pi}{\beta^3\alpha^2h^2}}$

4. $\sqrt{\frac{3m\pi}{\beta^3\alpha^2h^2}}$

Q19. [June 2016] . 5.0 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2016 June	5M

The internal energy $E(T)$ of a system at a fixed volume is found to depend on the temperature T as $E(T) = aT^2 + bT^4$. Then the entropy $S(T)$, as a function of temperature, is

1. $\frac{1}{2}aT^2 + \frac{1}{4}bT^4$
2. $2aT^2 + 4bT^4$
3. $2aT + \frac{4}{3}bT^3$
4. $2aT + 2bT^3$

Q20. [June 2016] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2016 June	5M

Consider electrons in graphene, which is a planar monatomic layer of carbon atoms. If the dispersion relation of the electrons is taken to be $\varepsilon(k) = ck$ (where c is constant) over the entire k-space, then the Fermi energy ε_F depends on the number density of electrons ρ as

1. $\varepsilon_F \propto \rho^{1/2}$
2. $\varepsilon_F \propto \rho$
3. $\varepsilon_F \propto \rho^{2/3}$
4. $\varepsilon_F \propto \rho^{1/3}$

Q21. [Dec 2017] . 3.5 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2017 Dec	3.5M

The dispersion relation of a gas of spin $\frac{1}{2}$ fermions in two dimensions is $E = \hbar v|\vec{k}|$, where E is the energy, $\vec{k}$ is the wave vector and v is a constant with the dimension of velocity. If the Fermi energy at zero temperature is ϵ_F, the number of particles per unit area is

1. $\frac{\epsilon_F}{(4\pi v\hbar)}$
2. $\frac{\epsilon_F^3}{(6\pi^2 v^3\hbar^3)}$
3. $\frac{\pi\epsilon_F^{3/2}}{(3v^3\hbar^3)}$
4. $\frac{\epsilon_F^2}{(2\pi v^2\hbar^2)}$

Q22. [Dec 2017] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2017 Dec	3.5M

The number of microstates of a gas of N particles in a volume V and of internal energy U, is given by

$$\Omega(U,V,N) = (V - Nb)^N \left(\frac{aU}{N}\right)^{3N/2}$$

(where a and b are positive constants). Its pressure P, volume V and temperature T, are related by

1. $\left(P + \frac{aN}{V}\right)(V - Nb) = Nk_BT$
2. $\left(P - \frac{aN}{V^2}\right)(V - Nb) = Nk_BT$
3. $PV = Nk_BT$
4. $P(V - Nb) = Nk_BT$

Q23. [Dec 2017] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2017 Dec	5M

Consider a quantum system of non-interacting bosons in contact with a particle bath. The probability of finding no particle in a given single particle quantum state is 10^{-6}. The average number of particles in that state is of the order of

1. 10^3
2. 10^6
3. 10^9
4. 10^{12}

Q24. [Dec 2017] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2017 Dec	5M

A closed system having three non-degenerate energy levels with energies $E = 0, \pm\epsilon$, is at temperature T. For $\epsilon = 2k_B T$, the probability of finding the system in the state with energy $E = 0$, is

1. $\frac{1}{(1+2\cosh 2)}$
2. $\frac{1}{(2\cosh 2)}$
3. $\frac{1}{2}\cos h\, 2$
4. $\frac{1}{\cosh 2}$

Q25. [Dec 2017] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2017 Dec	5M

Two non-degenerate energy levels with energies 0 and $\in$ are occupied by N noninteracting particles at a temperature T. Using classical statistics, the average internal energy of the system is

1. $\frac{N\in}{(1+e^{\in/k_BT})}$
2. $\frac{N\in}{(1-e^{\in/k_BT})}$
3. $N\in e^{-\epsilon/k_BT}$
4. $\frac{3}{2}Nk_BT$

Q26. [June 2017] . 3.5 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2017 June	3.5M

A gas of photons inside a cavity of volume V is in equilibrium at temperature T. If the temperature of the cavity is changed to $2T$, the radiation pressure will change by a factor of

1. 2
2. 16
3. 8
4. 4

Q27. [June 2017] . 3.5 marks
Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2017 June	3.5M

In a thermodynamic system in equilibrium, each molecule can exist in three possible states with probabilities $1/2, 1/3$ and $1/6$ respectively. The entropy per molecule is

1. $k_B l n 3$
2. $\frac{1}{2} k_B l n 2 + \frac{2}{3} k_B l n 3$
3. $\frac{2}{3} k_B l n 2 + \frac{1}{2} k_B l n 3$
4. $\frac{1}{2} k_B \ln 2 + \frac{1}{6} k_B \ln 3$

Q28. [June 2017] . 5.0 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2017 June	5M

The single particle energy levels of a non-interacting three-dimensional isotropic system, labelled by momentum k, are proportional to k^3. The ratio $\bar{P}/\in$ of the average pressure $\bar{P}$ to the energy density $\in$ at a fixed temperature, is

1. $1/3$
2. $2/3$
3. 1
4. 3

Q29. [June 2017] . 5.0 marks

Statistical Mechanics > Ising model

CSIR NET	2017 June	5M

The Hamiltonian for three Ising spins S_0, S_1 and S_2, taking values ± 1, is $H = -JS_0(S_1 + S_2)$

If the system is in equilibrium at temperature T, the average energy of the system, in terms of $\beta = (k_B T)^{-1}$, is

1. $-\frac{1+\cosh(2\beta J)}{2\beta \sinh(2\beta J)}$
2. $-2J[1 + cos\,h(2\beta J)]$
3. $-2/\beta$
4. $-2J\,\frac{\sinh(2\beta J)}{1+\cosh(2\beta J)}$

Q30. [Dec 2018] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2018 Dec	3.5M

The heat capacity C_V at constant volume of a metal, as a function of temperature, is $\alpha T + \beta T^3$, where α and β are constants. The temperature dependence of the entropy at constant volume is

1. $\alpha T + \frac{1}{3}\beta T^3$
2. $\alpha T + \beta T^3$
3. $\frac{1}{2}\alpha T + \frac{1}{3}\beta T^3$
4. $\frac{1}{2}\alpha T + \frac{1}{4}\beta T^3$

Q31. [Dec 2018] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2018 Dec	3.5M

The rotational energy levels of a molecule are $E_\ell = \frac{\hbar^2}{2I_0}\ell(\ell+1)$, where $\ell = 0,1,2,\ldots$ and I_0 is its moment of inertia. The contribution of the rotational motion to the Helmholtz free energy per molecule, at low temperatures in a dilute gas of these molecules, is approximately

1. $-k_BT\left(1+\frac{\hbar^2}{I_0k_BT}\right)$
2. $-k_BTe^{-\frac{\hbar^2}{I_0k_BT}}$
3. $-k_BT$
4. $-3k_BTe^{-\frac{\hbar^2}{I_0k_BT}}$

Q32. [Dec 2018] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2018 Dec	3.5M

The vibrational motion of a diatomic molecule may be considered to be that of a simple harmonic oscillator with angular frequency ω. If a gas of these molecules is at temperature T, what is the probability that a randomly picked molecule will be found in its lowest vibrational state?

1. $1 - e^{-\frac{\hbar\omega}{k_B T}}$
2. $e^{-\frac{\hbar\omega}{2k_B T}}$
3. $tan\,h\left(\frac{\hbar\omega}{k_B T}\right)$
4. $\frac{1}{2}\text{cosech}\left(\frac{\hbar\omega}{2k_B T}\right)$

Q33. [Dec 2018] . 3.5 marks

Statistical Mechanics > Grand Canonical ensemble

CSIR NET	2018 Dec	3.5M

Consider an ideal Fermi gas in a grand canonical ensemble at a constant chemical potential. The variance of the occupation number of the single particle energy level with mean occupation number $\bar{n}$ is

1. $\bar{n}(1-\bar{n})$
2. $\sqrt{\bar{n}}$
3. $\bar{n}$
4. $\frac{1}{\sqrt{\bar{n}}}$

Q34. [Dec 2018] . 5.0 marks

Statistical Mechanics > Ising model

CSIR NET	2018 Dec	5M

The Hamiltonian of a one-dimensional Ising model of N spins (N large) is

$$H = -J \sum_{i=1}^{N} \sigma_i \sigma_{i+1}$$

where the spin $\sigma_i = \pm 1$ and J is a positive constant. At inverse temperature $\beta = \frac{1}{k_B T}$, the correlation function between the nearest neighbor spins ($\sigma_i \sigma_{i+1}$) is

1. $\frac{e^{-\beta J}}{(e^{\beta J} + e^{-\beta J})}$
2. $e^{-2\beta J}$
3. $tanh(\beta J)$
4. $\coth(\beta J)$

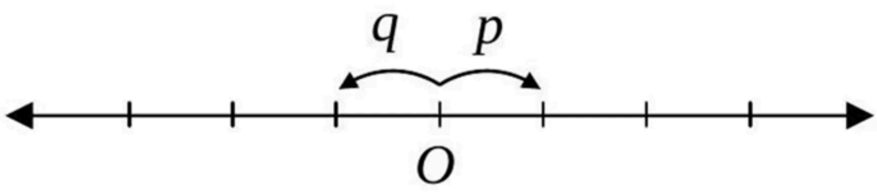
Q35. [Dec 2018] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2018 Dec	5M

A particle hops on a one-dimensional lattice with lattice spacing a. The probability of the particle to hop to the neighboring site to its right is p, while the corresponding probability to hop to the left is $q = 1 - p$. The root-mean squared deviation $\Delta x = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$ in displacement after N steps, is

1. $a\sqrt{Npq}$
2. $aN\sqrt{pq}$
3. $2a\sqrt{Npq}$
4. $a\sqrt{N}$



Q36. [Dec 2018] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2018 Dec	5M

The energy levels accessible to a molecule have energies $E_1 = 0, E_2 = \Delta$ and $E_3 = 2\Delta$ (where Δ is a constant). A gas of these molecules is in thermal equilibrium at temperature T. The specific heat at constant volume in the high temperature limit ($k_B T \gg \Delta$) varies with temperature as

1. $\frac{1}{T^{3/2}}$
2. $\frac{1}{T^3}$
3. $\frac{1}{T}$
4. $\frac{1}{T^2}$

Q37. [June 2018] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2018 June	3.5M

The number of ways of distributing 11 indistinguishable bosons in 3 different energy levels is

1. 3^{11}
2. 11^{3}
3. $\frac{(13)!}{2!(11)!}$
4. $\frac{(11)!}{3!8!}$

Q38. [June 2018] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2018 June	3.5M

In a system of N distinguishable particles, each particle can be in one of two states with energies 0 and $-E$, respectively. The mean energy of the system at temperature T is

1. $-\frac{1}{2}N\left(1+e^{\varepsilon/k_BT}\right)$
2. $-NE\left(1+e^{\varepsilon/k_BT}\right)$
3. $-\frac{1}{2}NE$
4. $-NE\left(1+e^{-\varepsilon/k_BT}\right)$

Q39. [June 2018] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2018 June	5M

Consider a particle diffusing in a liquid contained in a large box. The diffusion constant of the particle in the liquid is $1.0 \times 10^{-2}\ \mathrm{cm}^2/s$. The minimum time after which the root-mean-squared displacement becomes more than $6cm$ is

1. 10 min
2. 6 min
3. 30 min
4. $\sqrt{6}\ \mathrm{min}$

Q40. [June 2018] . 5.0 marks

Statistical Mechanics > Black Body Radiations

CSIR NET	2018 June	5M

The maximum intensity of solar radiation is at the wavelength of $\lambda_{\text{sun}} \sim 5000\text{Å}^{\circ}$ and corresponds to its surface temperature $T_{\text{sun}} \sim 10^4\,\text{K}$. If the wavelength of the maximum intensity of an X-ray star is 5Å°, its surface temperature is of the order of

1. $10^{16}\,K$
2. $10^{14}\,K$
3. $10^{10}\,K$
4. $10^{7}\,\text{K}$

Q41. [Dec 2019] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2019 Dec	3.5M

The angular frequency of oscillation of a quantum harmonic oscillator in two dimensions is ω. If it is in contact with an external heat bath at temperature T, its partition function is (in the following $\beta = \frac{1}{k_B T}$)

1. $\frac{e^{2\beta\hbar\omega}}{\left(e^{2\beta\hbar\omega}-1\right)^2}$
2. $\frac{e^{\beta\hbar\omega}}{\left(e^{\beta\hbar\omega}-1\right)^2}$
3. $\frac{e^{\beta\hbar\omega}}{e^{\beta\hbar\omega}-1}$
4. $\frac{e^{2\beta\hbar\omega}}{e^{2\beta\hbar\omega}-1}$

Q42. [Dec 2019] . 3.5 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2019 Dec	3.5M

Consider black body radiation in thermal equilibrium contained in a two-dimensional box. The dependence of the energy density on the temperature T is

1. T^3
2. T
3. T^2
4. T^4

Q43. [Dec 2019] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2019 Dec	3.5M

Two spin $\frac{1}{2}$ fermions of mass m are confined to move in a one-dimensional infinite potential well of width L. If the particles are known to be in a spin triplet state, the ground state energy of the system (in units of $\frac{\hbar^2\pi^2}{2mL^2}$) is

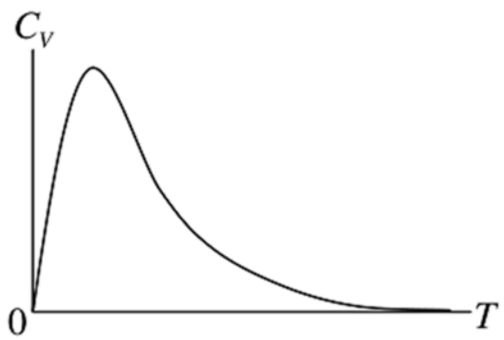
1. 8
2. 2
3. 3
4. 5

Q44. [Dec 2019] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2019 Dec	3.5M

The energies available to a three state system are $0, E$ and $2E$, where $E > 0$. Which of the following graphs best represents the temperature dependence of the specific heat?

1.


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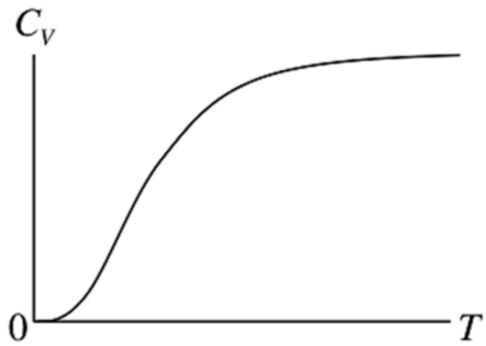

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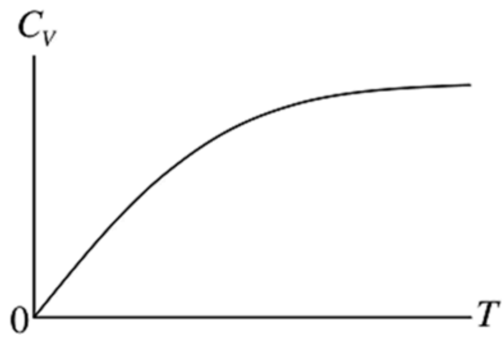

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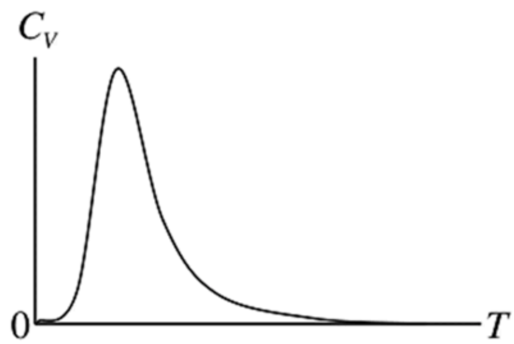


Q45. [Dec 2019] . 5.0 marks
Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2019 Dec	5M

A particle hops randomly from a site to its nearest neighbour in each step on a square lattice of unit lattice constant. The probability of hopping to the positive x-direction is 0.3 , to the negative x-direction is 0.2 , to the positive y-direction is 0.2 and to the negative y-direction is 0.3 . If a particle starts from the origin, its mean position after N steps is

1. $\frac{1}{10}N(-\hat{i}+\hat{j})$
2. $\frac{1}{10}N(\hat{i}-\hat{j})$
3. $N(0.3\hat{i}-0.2\hat{j})$
4. $N(0.2\hat{i}-0.3\hat{j})$

Q46. [Dec 2019] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2019 Dec	5M

For a crystal, let ϕ denote the energy required to create a pair of vacancy and interstitial defects. If n pairs of such defects are formed, and $n \ll N, N'$, where N and N' are respectively, the total number of lattice and interstitial sites, then n is approximately

1. $\sqrt{NN'}e^{-\phi/(2k_BT)}$
2. $\sqrt{NN'}e^{-\phi/(k_BT)}$
3. $\frac{1}{2}(N+N')e^{-\phi/(2k_BT)}$
4. $\frac{1}{2}(N+N')e^{-\phi/(k_BT)}$

Q47. [Dec 2019] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2019 Dec	5M

The Hamiltonian of two particles, each of mass m, is $H(q_1,p_1;q_2,p_2)=\frac{p_1^2}{2m}+\frac{p_2^2}{2m}+k\left(q_1^2+q_2^2+\frac{1}{4}q_1q_2\right)$, where $k>0$ is a constant. The value of the partition function

$Z(\beta)$

$$=\int_{-\infty}^{\infty}dq_1\int_{-\infty}^{\infty}dp_1\int_{-\infty}^{\infty}dq_2\int_{-\infty}^{\infty}dp_2 e^{-\beta H(q_1,p_1;q_2,p_2)}$$ is

1. $\frac{2m\pi^2}{k\beta^2}\sqrt{\frac{16}{15}}$
2. $\frac{2m\pi^2}{k\beta^2}\sqrt{\frac{15}{16}}$
3. $\frac{2m\pi^2}{k\beta^2}\sqrt{\frac{63}{64}}$
4. $\frac{2m\pi^2}{k\beta^2}\sqrt{\frac{64}{63}}$

Q48. [June 2019] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2019 June	3.5M

In a system comprising of approximately 10^{23} distinguishable particles, each particle may occupy any of 20 distinct states. The maximum value of the entropy per particle is nearest to

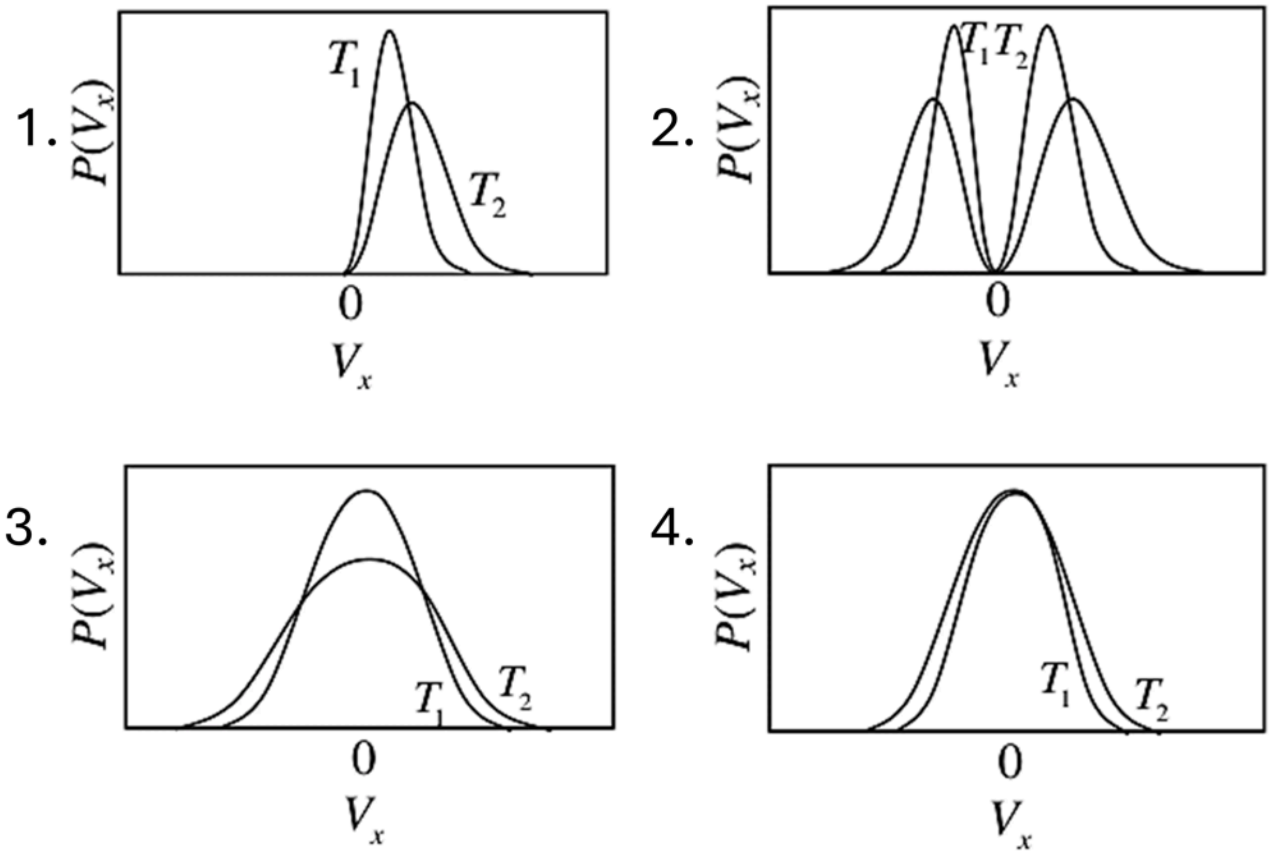
1. $20k_B$
2. $3k_B$
3. $10(\ln 2)k_B$
4. $20(\ln 2)k_B$

Q49. [June 2019] . 3.5 marks

Statistical Mechanics > Black Body Radiations

CSIR NET	2019 June	3.5M

Consider a classical gas in thermal equilibrium at temperatures T_1 and T_2 where $T_1 < T_2$. Which of the following graphs correctly represents the qualitative behavior of the probability density function of the x-component of the velocity?



Q50. [June 2019] . 5.0 marks
Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2019 June	5M

At each time step, a random walker in one dimension either remains at the same point with probability $\frac{1}{4}$, or moves by a distance Δ to the right or left with probabilities $\frac{3}{8}$ each. After N time steps, its root mean squared displacement is

1. $\Delta\sqrt{N}$
2. $\Delta\sqrt{\frac{9N}{16}}$
3. $\Delta\sqrt{\frac{3N}{4}}$
4. $\Delta\sqrt{\frac{3N}{8}}$

Q51. [June 2019] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2019 June	5M

The Hamiltonian of three Ising spins S_1, S_2 and S_3, each taking values ± 1, is

$H = -J(S_1S_2 + S_2S_3) - hS_1$, where J and h are positive constants. The mean value of S_3 in equilibrium at a temperature $T = 1/(k_B\beta)$, is

1. $\tanh^3(\beta J)$
2. $\tan(\beta h)\tanh^2(\beta J)$
3. $\sinh(\beta h)\sinh^2(\beta J)$
4. 0

Q52. [June 2020] . 3.5 marks
Statistical Mechanics > Black Body Radiations

CSIR NET	2020 June	3.5M

The temperatures of two perfect black bodies A and B are 400K and 200K, respectively. If the surface area of A is twice that of B, the ratio of total power emitted by A to that by B is

1. 4
2. 2
3. 32
4. 16

Q53. [June 2020] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2020 June	3.5M

An idealised atom has a non-degenerate ground state at zero energy and a g-fold degenerate excited state of energy E. In a non-interacting system of N such atoms, the population of the excited state may exceed that of the ground state above a temperature $T > \frac{E}{2k_B \ln 2}$. The minimum value of g for which this is possible is

1. 8
2. 4
3. 2
4. 1

Q54. [June 2020] . 5.0 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2020 June	5M

Spin $\frac{1}{2}$ fermions of mass m and 4m are in a harmonic potential $V(x) = \frac{1}{2}kx^2$. Which configuration of 4 such particles has the lowest value of the ground state energy?

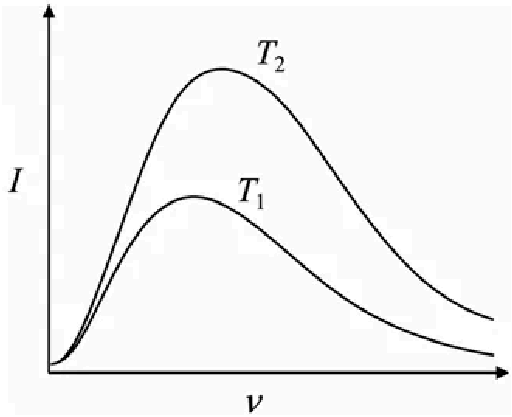
1. 4 particles of mass m
2. 4 particles of mass 4m
3. 1 particle of mass m and 3 particles of mass 4m
4. 2 particles of mass m and 2 particles of mass 4m

Q55. [June 2020] . 5.0 marks
Statistical Mechanics > Black Body Radiations

CSIR NET	2020 June	5M

The energy density I of a black body radiation at temperature T is given by the Planck's distribution function $I(v,T) = \frac{8\pi v^2}{c^3}\frac{hv}{\left(e^{\frac{hv}{k_B T}}-1\right)}$, where v is the frequency. The function $I(v,T)$ for two different temperatures T_1 and T_2 are shown below. If the two curves coincide when $I(v,T)v^a$ is plotted against v^b/T, then the values of a and b are, respectively,

1. 2 and 1
2. -2 and 2
3. 3 and -1
4. -3 and 1



Q56. [June 2020] . 5.0 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2020 June	5M

For an ideal gas consisting of N distinguishable particles in a volume V, the probability of finding exactly 2 particles in a volume $\delta V \ll V$, in the limit $N, V \to \infty$, is

1. $2N\delta V/V$
2. $(N\delta V/V)^2$
3. $\frac{(N\delta V)^2}{2V^2} e^{-N\delta V/V}$
4. $\left(\frac{\delta V}{V}\right)^2 e^{-N\delta V/V}$

Q57. [June 2020] . 5.0 marks

Statistical Mechanics > Ising model

CSIR NET	2020 June	5M

The Hamiltonian of a system of 3 spins is $H = J(S_1S_2 + S_2S_3)$, where $S_i = \pm 1$ for $i = 1,2,3$. Its canonical partition function, at temperature T, is

1. $2\left(2\sinh\frac{J}{k_BT}\right)^2$
2. $2\left(2\cosh\frac{J}{k_BT}\right)^2$
3. $2\left(2\cosh\frac{J}{k_BT}\right)$
4. $2\left(2\cosh\frac{J}{k_BT}\right)^3$

Q58. [June 2021] . 3.5 marks

Statistical Mechanics > Black Body Radiations

CSIR NET	2021 June	3.5M

The volume and temperature of a spherical cavity filled with black body radiation are V and 300 K, respectively. If it expands adiabatically to a volume $2V$, its temperature will be closest to

1. 150 K
2. 300 K
3. 250 K
4. 240 K

Q59. [June 2021] . 3.5 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2021 June	3.5M

The position of a particle in one dimension changes in discrete steps. With each step it moves to the right, however, the length of the step is drawn from a uniform distribution from the interval $\left[\lambda - \frac{1}{2}w, \lambda + \frac{1}{2}w\right]$, where λ and w are positive constants. If X denotes the distance from the starting point after N steps, the standard deviation $\sqrt{\langle X^2 \rangle - \langle X \rangle^2}$ for large values of N is

1. $\frac{\lambda}{2} \times \sqrt{N}$
2. $\frac{\lambda}{2} \times \sqrt{\frac{N}{3}}$
3. $\frac{w}{2} \times \sqrt{N}$
4. $\frac{w}{2} \times \sqrt{\frac{N}{3}}$

Q60. [June 2021] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2021 June	5M

The energy levels of a non-degenerate quantum system are $\epsilon_n = nE_0$, where E_0 is a constant and $n = 1,2,3, \ldots$. At a temperature T, the free energy F can be expressed in terms of the average energy E by

1. $E_0 + k_B T \ln \frac{E}{E_0}$
2. $E_0 + 2k_B T \ln \frac{E}{E_0}$
3. $E_0 - k_B T \ln \frac{E}{E_0}$
4. $E_0 - 2k_B T \ln \frac{E}{E_0}$

Q61. [June 2021] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2021 June	5M

A polymer, made up of N monomers, is in thermal equilibrium at temperature T. Each monomer could be of length a or 2a. The first contributes zero energy, while the second one contributes $\in$. The average length (in units of Na) of the polymer at temperature $T = \in/k_B$ is

1. $\frac{5+e}{4+e}$
2. $\frac{4+e}{3+e}$
3. $\frac{3+e}{2+e}$
4. $\frac{2+e}{1+e}$

Q62. [June 2021] . 5.0 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2021 June	5M

Balls of ten different colours labeled by $a = 1,2,\ldots,10$ are to be distributed among different coloured boxes. A ball can only go in a box of the same colour, and each box can contain at most one ball. Let n_a and N_a denote respectively, the numbers of balls and boxes of colour a. Assuming that $N_a \gg n_a \gg 1$, the total entropy (in units of the Boltzmann constant) can be best approximated by

1. $\sum_a (N_a \ln N_a + n_a \ln n_a - (N_a - n_a)\ln(N_a - n_a)$
2. $\sum_a \left(N_a \ln N_a - n_a \ln n_a + (N_a - n_a)\ln(N_a - n_a)\right)$
3. $\sum_a \left(N_a \ln N_a - n_a \ln n_a + (N_a - n_a)\ln(N_a - n_a)\right)$
4. $\sum_a \left(N_a \ln N_a + n_a \ln n_a + (N_a - n_a)\ln(N_a - n_a)\right)$

Q63. [June 2021] . 5.0 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2021 June	5M

The dispersion relation of a gas of non-interacting bosons in d dimensions $E(k) = ak^s$ where a and s are positive constants, Bose-Einstein condensation will occur for all values of

1. $d > s$
2. $d + 2 > s > d - 2$
3. $s > 2$ independent of d
4. $d > 2$ independent of s

Q64. [June 2022] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2022 June	3.5M

If the average energy $\langle E\rangle_T$ of a quantum harmonic oscillator at a temperature T is such that $\langle E\rangle_T = 2\langle E\rangle_{T\to 0}$, then T satisfies

1. $coth\left(\frac{\hbar\omega}{k_BT}\right) = 2$
2. $coth\left(\frac{\hbar\omega}{2k_BT}\right) = 2$
3. $coth\left(\frac{\hbar\omega}{k_BT}\right) = 4$
4. $\coth\left(\frac{\hbar\omega}{2k_BT}\right) = 4$

Q65. [June 2022] . 3.5 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2022 June	3.5M

A walker takes steps, each of length L, randomly in the directions along east, west, north and south. After four steps its distance from the starting point is d. The probability that $d \leq 3L$ is

1. $63/64$
2. $59/64$
3. $57/64$
4. 55/64

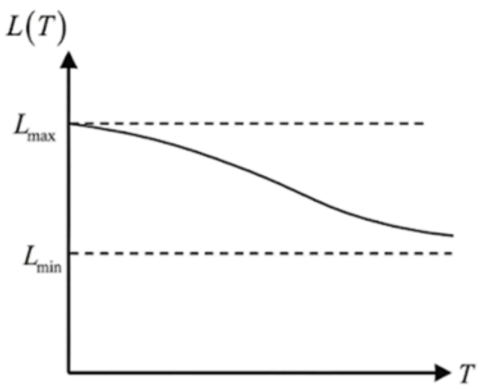
Q66. [June 2022] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2022 June	3.5M

An elastic rod has a low energy state of length L_{max} and high energy state of length L_{min}. The best schematic representation of the temperature (T) dependence of the mean equilibrium length L(T) of the rod, is

1.



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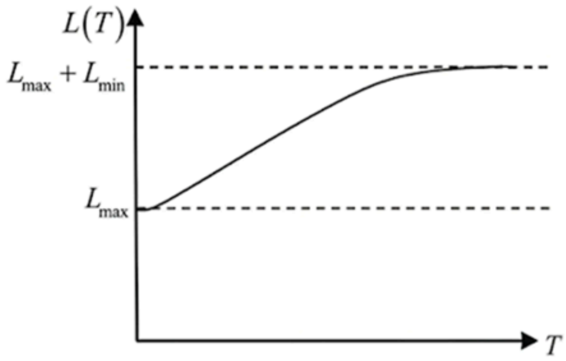

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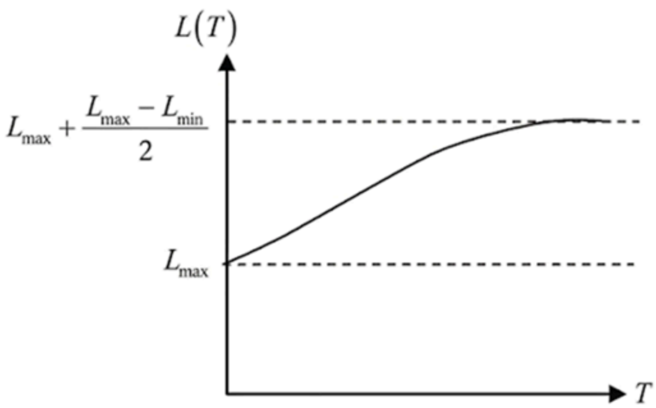

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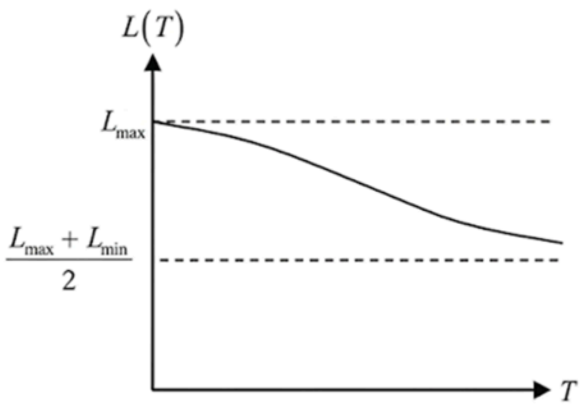


Q67. [June 2022] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2022 June	5M

The energy levels of a system, which is in equilibrium at temperature $T = 1/(k_B\beta)$, are $0, \in$ and $2 \in$. If two identical bosons occupy these energy levels, the probability of the total energy being $3 \in$, is

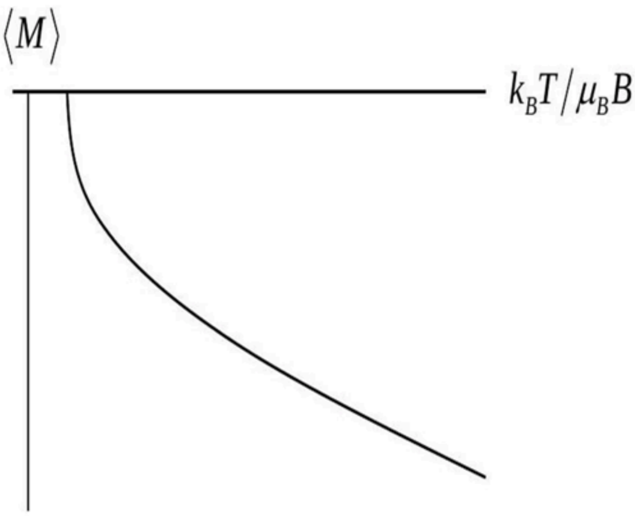
1. $\frac{e^{-3\beta\epsilon}}{1+e^{-\beta\epsilon}+e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$
2. $\frac{e^{-3\beta\epsilon}}{1+2e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$
3. $\frac{e^{-3\beta\epsilon}}{e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$
4. $\frac{e^{-3\beta\epsilon}}{1+e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$

Q68. [June 2022] . 5.0 marks
Statistical Mechanics > Canonical Ensemble

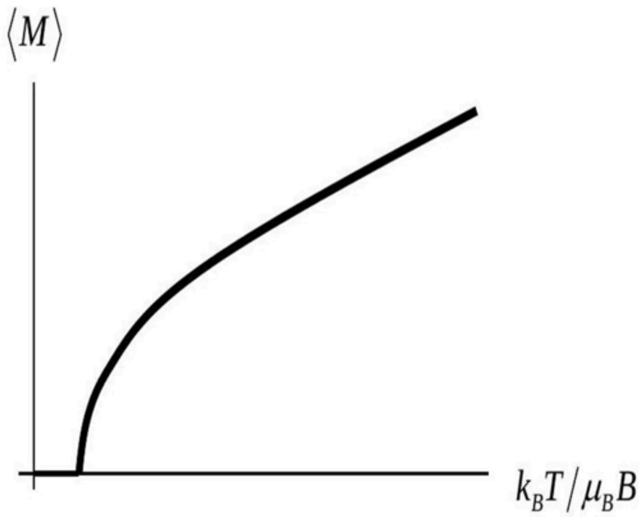
CSIR NET	2022 June	5M

A paramagnetic salt with magnetic moment per ion $\mu_{\pm} = \pm\mu_B$ (where μ_B is the Bohr magneton) is in thermal equilibrium at temperature T in a constant magnetic field B. The average magnetic moment $\langle M \rangle$, as a function of $\frac{k_B T}{\mu_B B}$, is best represented by

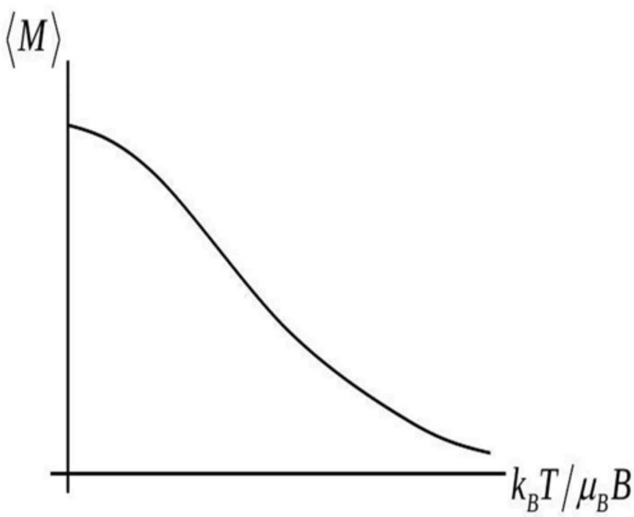
1.



2.



3.



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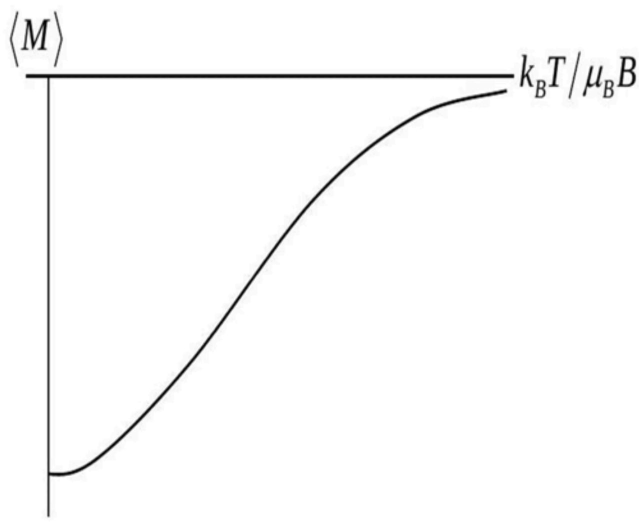


Q69. [June 2022] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2022 June	5M

A system of N non-interacting particles in one-dimension, each of which is in a potential $V(x) = gx^6$ where $g > 0$ is a constant and x denotes the displacement of the particle from its equilibrium position. In thermal equilibrium, the heat capacity at constant volume is

1. $\frac{7}{6} N k_B$
2. $\frac{4}{3} N k_B$
3. $\frac{3}{2} N k_B$
4. $\frac{2}{3} N k_B$

Q70. [June 2022] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2022 June	5M

The energies of a two-level system are $\pm E$. Consider an ensemble of such non-interacting systems at a temperature T. At low temperatures, the leading term in the specific heat depends on T as

1. $\frac{1}{T^2}e^{-E/k_BT}$
2. $\frac{1}{T^2}e^{-2E/k_BT}$
3. T^2e^{-E/k_BT}
4. T^2e^{-2E/k_BT}

Q71. [Dec 2023] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2023 Dec	3.5 M

A quantum system is described by the Hamiltonian

$$H = JS_z + \lambda S_x$$

where $S_i = \frac{\hbar}{2}\sigma_i$ and $\sigma_i (i = x, y, z)$ are the Pauli matrices. If $0 < \lambda \ll J$, then the leading correction in λ to the partition function of the system at temperature T is

1. $\frac{\hbar\lambda^2}{2Jk_BT} \coth\left(\frac{J\hbar}{2k_BT}\right)$
2. $\frac{\hbar\lambda^2}{2Jk_BT} \tanh\left(\frac{J\hbar}{2k_BT}\right)$
3. $\frac{\hbar\lambda^2}{2Jk_BT} \cosh\left(\frac{J\hbar}{2k_BT}\right)$
4. $\frac{\hbar\lambda^2}{2Jk_BT} \sinh\left(\frac{J\hbar}{2k_BT}\right)$

Q72. [Dec 2023] . 3.5 marks
Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 Dec	3.5 M

Each allowed energy level of a system of non-interacting fermions has a degeneracy M. If there are N fermions and R is the remainder upon dividing N by M , then the degeneracy of the ground state is

1. R^M
2. 1
3. M
4. ${}^{M}C_{R}$

Q73. [Dec 2023] . 3.5 marks
Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 Dec	3.5 M

Four distinguishable particle fill up energy levels $0, \in, 2 \in$. The number of available microstates for the total energy $4 \in$ is

1. 20
2. 24
3. 11
4. 19

Q74. [Dec 2023] . 3.5 marks
Statistical Mechanics > Canonical Ensemble

CSIR NET	2023 Dec	3.5 M

A system of N non-interacting classical spins, where each spin can take values $\sigma = -1,0,1$, is placed in a magnetic field h. The single spin Hamiltonian is given by

$$H = -\mu_B h\sigma + \Delta(1-\sigma^2),$$

where μ_B, Δ are positive constants with appropriate dimensions. If M is the magnetization, the zero-field magnetic susceptibility per spin $\frac{1}{N}\frac{\partial M}{\partial h}\Big|_{h\to 0}$, at a temperature $T = 1/\beta k_B$ is given by

1. $\beta\mu_B^2$
2. $\frac{2\beta\mu_B^2}{2+e^{-\beta\Delta}}$
3. $\beta\mu_B^2 e - \beta\Delta$
4. $\frac{\beta\mu_B^2}{1+e^{-\beta\Delta}}$

Q75. [Dec 2023] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2023 Dec	5 M

A system of non-relativistic and non-interacting bosons of mass m in two dimensions has a density n. The Bose-Einstein condensation temperature T_c is

1. $\frac{12n\hbar^2}{\pi m k_B}$
2. $\frac{3n\hbar^2}{\pi m k_B}$
3. $\frac{6n\hbar^2}{\pi m k_B}$
4. 0

Q76. [Dec 2023] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2023 Dec	5 M

A photon inside the sun executes a random walk process. Given the radius of the sun $\approx 7 \times 10^8$ km and mean free path of a photon $\approx 10^{-3}$ m, the time taken by the photon to travel from the centre to the surface of the sun is closest to

1. 10^6sec
2. 10^{24}sec
3. 10^{12}sec
4. 10^{18}sec

Q77. [June 2023] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2023 June	3.5M

Two energy levels, 0 (non-degenerate) and ϵ (doubly degenerate), are available to N non-interacting distinguishable particles. If U is the total energy of the system, for large values of N the entropy of the system is $k_B\left[N\ln N-\left(N-\frac{U}{\epsilon}\right)\ln\left(N-\frac{U}{\epsilon}\right)+X\right]$. In this expression, X is

1. $-\frac{U}{\epsilon}\ln\frac{U}{2\epsilon}$
2. $-\frac{U}{\epsilon}\ln\frac{2U}{\epsilon}$
3. $-\frac{2U}{\epsilon}\ln\frac{2U}{\epsilon}$
4. $-\frac{U}{\epsilon}\ln\frac{U}{\epsilon}$

Q78. [June 2023] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 June	3.5M

The single particle energies of a system of N non-interacting fermions of spin s (at $T = 0$) are $E_n = n^2 E_0$, $n = 1,2,3 \cdots$. The ratio $\epsilon_F\left(\frac{3}{2}\right)/\epsilon_F\left(\frac{1}{2}\right)$ of the Fermi energies for fermions of spin $3/2$ and spin $1/2$, is

1. 1/2
2. 1/4
3. 2
4. 1

Q79. [June 2023] . 3.5 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2023 June	3.5M

The dispersion relation of a gas of non-interacting bosons in two dimensions is $E|k| = c\sqrt{|k|}$, where c is a positive constant. At low temperatures, the leading dependence of the specific heat on temperature T, is

1. T^4
2. T^3
3. T^2
4. $T^{3/2}$

Q80. [June 2023] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 June	3.5M

The energy levels available to each electron in a system of N non-interacting electrons are $E_n = nE_0$, $n = 0,1,2,\cdots$. A magnetic field, which does not affect the energy spectrum, but completely polarizes the electron spins, is applied to the system. The change in the ground state energy of the system is

1. $\frac{1}{2}N^2E_0$
2. N^2E_0
3. $\frac{1}{8}N^2E_0$
4. $\frac{1}{4}N^2E_0$

Q81. [June 2023] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2023 June	5M

Two random walkers A and B walk on a one-dimensional lattice. The length of each step taken by A is one, while the same for B is two, however, both move towards right or left with equal probability. If they start at the same point, the probability that they meet after 4 steps, is

1. 9/64
2. 5/32
3. 11/64
4. 3/16

Q82. [June 2023] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2023 June	5M

In a one-dimensional system of N spins, the allowed values of each spin are $\sigma_i = \{1,2,3, \dots, q\}$, where $q \geq 2$ is an integer. The energy of the system is $-J\sum_{i=1}^{N} \delta_{\sigma_i,\sigma_{i+1}}$ where $J > 0$ is a constant. If periodic boundary conditions are imposed, the number of ground states of the system is

1. q
2. Nq
3. q^N
4. 1

Q83. [June 2023] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2023 June	5M

The dispersion relation of electrons in three dimensions is $\epsilon(k) = \hbar v_F k$, where v_F is the Fermi velocity. If at low temperatures ($T \ll T_F$) the Fermi energy ϵ_F depends on the number density n as $\epsilon_F(n) \sim n^\alpha$, the value of α is

1. 1/3
2. 2/3
3. 1
4. 3/5

Q84. [June 2023] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2023 June	5M

Two electrons in thermal equilibrium at temperature $T = k_B/\beta$ can occupy two sites. The energy of the configuration in which they occupy the different sites is $J\mathbf{S}_1 \cdot \mathbf{S}_2$ (where $J > 0$ is a constant and $\mathbf{S}$ denotes the spin of an electron), while it is U if they are at the same site. If $U = 10J$, the probability for the system to be in the first excited state is

1. $e^{-3\beta J/4}/\left(3e^{\beta J/4} + e^{-3\beta J/4} + 2e^{-10\beta J}\right)$
2. $3e^{-\beta J/4}/\left(3e^{-\beta J/4} + e^{3\beta J/4} + 2e^{-10\beta J}\right)$
3. $e^{-\beta J/4}/\left(2e^{-\beta J/4} + 3e^{3\beta J/4} + 2e^{-10\beta J}\right)$
4. $3e^{-3\beta J/4}/\left(2e^{\beta J/4} + 3e^{-3\beta J/4} + 2e^{-10\beta J}\right)$

Q85. [Dec 2024] . 3.5 marks
Statistical Mechanics > Black Body Radiations

CSIR NET	2024 Dec	3.5M

A spherical cavity of volume V is filled with thermal radiation at temperature T. The cavity expands adiabatically to 8 times its initial volume. If σ is Stefan's constant and c is the speed of light in vacuum, what is the closest value of the work done in the process?

1. $8\left(\frac{\sigma T^4 V}{c}\right)$

2. $4\left(\frac{\sigma T^4 V}{c}\right)$

3. $\frac{1}{2}\left(\frac{\sigma T^4 V}{c}\right)$

4. $2\left(\frac{\sigma T^4 V}{c}\right)$

Q86. [Dec 2024] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2024 Dec	3.5M

An isolated box of volume V contains 5 identical, but distinguishable and noninteracting particles. The particles can either be in the ground state of zero energy or in an excited state of energy ε. The ground state is non-degenerate while the excited state is doubly degenerate. There is no restriction on the number of particles that can be put in a given state. The number of accessible microstates corresponding to the macrostate of the system with energy $E = 2\varepsilon$ are

1. 10
2. 20
3. 40
4. 30

Q87. [Dec 2024] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2024 Dec	3.5M

A system comprises of N distinguishable atoms ($N \gg 1$). Each atom has two energy levels ω and $3\omega(\omega > 0)$. Let ε_{eq} denote the average energy per particle when the system is in thermal equilibrium, the upper limit of ε_{eq} is

1. $\frac{3\omega}{2}$
2. 3ω
3. $\frac{5\omega}{2}$
4. 2ω

Q88. [Dec 2024] . 3.5 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2024 Dec	3.5M

For an ideal Bose gas, the density of states is given by $\rho(E) = CE^2$, where C is a positive constant. Assume that the number of bosons is not conserved. The variation of the specific heat of the gas with temperature T is closest to

1. T^2
2. T^3
3. T
4. T^4

Q89. [Dec 2024] . 5.0 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2024 Dec	5M

Bose condensation experiments are carried out on two samples A and B of an ideal Bose gas. The same gas species is used in both. The condensate densities achieved at a given temperature below the critical temperature are $n_{\mathrm{A}} = 1.80 \times 10^{14}\ \mathrm{cm}^{-3}$ and $n_{\mathrm{B}} = 1.44 \times 10^{15}\ \mathrm{cm}^{-3}$, respectively. If P_{A} and P_{B} are the pressures of the two gas samples, the ratio $\frac{P_{\mathrm{A}}}{P_{\mathrm{B}}}$ is

1. 1
2. $\left(\frac{1}{8}\right)^{\frac{3}{2}}$
3. $\left(\frac{1}{8}\right)^{\frac{2}{3}}$
4. 8

Q90. [Dec 2024] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2024 Dec	5M

Energy of two Ising spins $\left(s = \pm\frac{1}{2}\right)$ is given by

$$E = s_1 s_2 + s_1 + s_2.$$

At temperature T, the probability that both spins take the value $-\frac{1}{2}$ is 16 times the probability that both take the value $+\frac{1}{2}$. At the same temperature, what is the probability that the spins take opposite values?

1. $\frac{16}{25}$
2. $\frac{8}{25}$
3. $\frac{8}{33}$
4. $\frac{16}{33}$

Q91. [Dec 2024] . 5.0 marks
Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2024 Dec	5M

A spherical cavity of radius r_0 has an impenetrable wall. A quantum particle of mass m inside the cavity is in its ground state. The pressure exerted on the cavity wall is

1. $\frac{\pi\hbar^2}{4mr_0^5}$
2. $\frac{\pi\hbar^2}{mr_0^5}$
3. $\frac{\pi^2\hbar^2}{2mr_0^5}$
4. $\frac{\pi^2\hbar^2}{4mr_0^5}$

Q92. [June 2024] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2024 June	3.5M

Quantum particles of unit mass, in a potential

$$V(x) = \begin{cases} \frac{1}{2}\omega^2 x^2 & x > 0 \\ \infty & x \le 0 \end{cases}$$

are in equilibrium at a temperature T. Let n_2 and n_3 denote the numbers of the particles in the second and third excited states respectively. The ratio n_2/n_3 is given by

1. $exp\left(\frac{2\hbar\omega}{k_B T}\right)$
2. $exp\left(\frac{\hbar\omega}{k_B T}\right)$
3. $exp\left(\frac{3\hbar\omega}{k_B T}\right)$
4. $\exp\left(\frac{4\hbar\omega}{k_B T}\right)$

Q93. [June 2024] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2024 June	3.5M

A single particle can exist in two states with energies 0 and E respectively. At high temperatures $(k_B T \gg E)$ the specific heat of the system (C_V) will be approximately

1. proportional to $\frac{1}{T}$
2. proportional to $\frac{1}{T^2}$
3. proportional to $e^{\frac{E}{k_B T}}$
4. constant

Q94. [June 2024] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2024 June	3.5M

Two non-interacting classical particles having masses m_1 and m_2 are moving in a one-dimensional box of length L. For total energy not exceeding a given value E, the phase space "volume" is given by

1. $\pi L^2 E\left(\frac{m_1 m_2}{m_1+m_2}\right)$
2. $\pi L^2 E\sqrt{m_1 m_2}$
3. $2\pi L^2 E\left(\frac{m_1 m_2}{m_1+m_2}\right)$
4. $2\pi L^2 E\sqrt{m_1 m_2}$

Q95. [June 2024] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2024 June	5M

A random walker takes a step of unit length towards right or left at any discrete time step. Starting from $x = 0$ at time $t = 0$, it goes right to reach $x = 1$ at $t = 1$. Hereafter if it repeats the direction taken in the previous step with probability p, the probability that it is again at $x = 1$ at $t = 3$ is

1. $1 - p$
2. $(1 - p)^2$
3. $2p(1 - p)$
4. $4p^2(1 - p)$

Q96. [June 2024] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2024 June	5M

Five classical spins are placed at the vertices of a regular pentagon. The Hamiltonian of the system is $H = J\sum S_i S_j$, where $J > 0, S_i = \pm 1$ and the sum is over all possible nearest neighbour pairs. The degeneracy of the ground state is

1. 8
2. 5
3. 4
4. 10

Q97. [Dec 2025] . 3.5 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2025 Dec	3.5M	Stat. Mech.

A 1-dimensional random walker's displacement is always positive and is equally likely to be anywhere in the range $[L, L+b]$. After N statistically independent steps the mean distance covered by the walker is

1. NL
2. $N\sqrt{L^2+b^2}$
3. $N\left(L+\frac{b}{2}\right)$
4. $NL+b\sqrt{N}$

Q98. [Dec 2025] . 3.5 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2025 Dec	3.5M	Stat. Mech.

B, C and F are three systems which have particles of same mass and same number density kept at the same low temperature T. Here C is a classical ideal gas, F is a free Fermi gas and B is a free Bose gas, with pressures P_C, P_F and P_B respectively. Then

1. $P_B > P_C > P_F$.
2. $P_F > P_C > P_B$.
3. $P_C > P_F > P_B$.
4. $P_c > P_B > P_F$.

Q99. [Dec 2025] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2025 Dec	3.5M	Stat. Mech.

Five indistinguishable atoms are sitting on the distinguishable vertices of a pentagon. The atoms can be in one of the two states: g with energy 0 , and e with energy E. However neighboring atoms cannot both be in the e state. The partition function of this system at temperature T, is

1. $1 + 5e^{-\frac{E}{k_B T}} + 2e^{-\frac{2E}{k_B T}}$
2. $1 + 5e^{-\frac{E}{k_B T}} + 3e^{-\frac{2E}{k_B T}}$
3. $1 + 5e^{-\frac{E}{k_B T}} + 10e^{-\frac{2E}{k_B T}}$
4. $1 + 5e^{-\frac{E}{k_B T}} + 5e^{-\frac{2E}{k_B T}}$

Q100. [Dec 2025] . 5.0 marks
Statistical Mechanics > Ising model

CSIR NET	2025 Dec	5M	Stat. Mech.

A binary alloy consists of N_A number of A-type and N_B number of B-type atoms. The atoms sit on the sites of a simple cubic lattice and the nearest neighbours interact with each other. Assume an attractive interaction energy $-J(J>0)$ between two like neighbours (AA or BB pair) and a repulsive interaction energy $+J$ between two unlike neighbours (AB pair). If N is the total number of sites, then the average energy of the system at a very high temperature ($k_B T \gg J$) is

1. $-3J\frac{(N_A-N_B)^2}{N}$
2. $3JN$
3. $3j\frac{(N_A+N_B)^2}{N}$
4. $-3J(N_A-N_B)$

Q101. [Dec 2025] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2025 Dec	5M	Stat. Mech.

Consider a one-dimensional lattice (with lattice spacing a) along X -axis with sites labelled by $x = 0,1,2 \ldots\ldots L$. A particle carrying a charge $-q$ can occupy any one of these sites. An electric field of strength E is applied in the positive x-direction. The average energy of the particle at a temperature T (in the limit $L \to \infty$) is $\left(\beta = \frac{1}{k_B T}\right)$

1. $\frac{Eqa}{e^{\beta Eqa} - 1}$
2. $\frac{Eqa}{1 + e^{\beta Eqa}}$
3. $\frac{Eqa}{2}$
4. $-Eqa$

Q102. [Dec 2025] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2025 Dec	5M	Stat. Mech.

The excitations of a three-dimensional solid are bosonic in nature and their energy dispersion is given by $\epsilon_k \propto k^2$, in the long wavelength limit. If the chemical potential of the system is zero, the temperature dependence of specific heat of the system at low temperature is proportional to

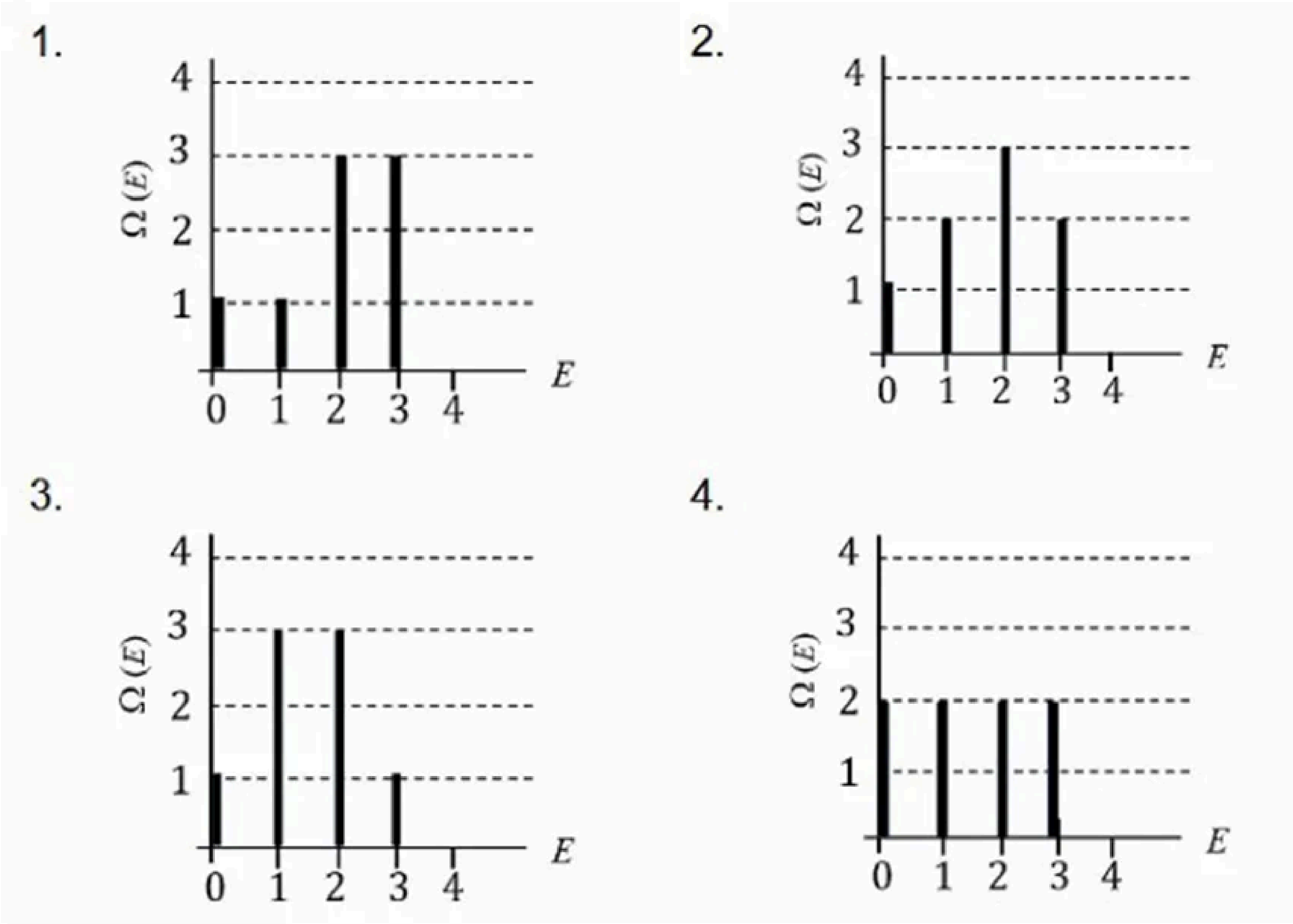
1. T^3
2. $T^{\frac{3}{2}}$
3. $T^{\frac{5}{2}}$
4. $T^{\frac{1}{2}}$

Q103. [June 2025] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2025 June	3.5M	Stat. Mech.

There are two boxes, one at the ground level, and the other at a fixed height h. There are three balls of different colours, each having mass m and radius $r \ll h$. There is no restriction on the number of balls that can be simultaneously put in a given box. For a given value of the total energy E (in units of mgh, g being the acceleration due to gravity), the number of accessible microstates is $\Omega(E)$. The plot of $\Omega(E)$ vs E is



Q104. [June 2025] . 3.5 marks

Statistical Mechanics > Microcanonical Ensemble

CSIR NET	2025 June	3.5M	Stat. Mech.

The internal energy of a system is given by

$U = g(N)V^{-\frac{2}{3}}\exp\left[\frac{2S}{3NR}\right]$, where V is the volume, S is the entropy, N is the number of molecules and R is a constant. The function $g(N)$ is proportional to

1. $N^{5/3}$
2. $N^{1/3}$
3. $N^{2/3}$
4. N

Q105. [June 2025] . 5.0 marks

Statistical Mechanics > Ising model

CSIR NET	2025 June	5M	Stat. Mech.

Consider $2N$ Ising spins, $s_i (s_i = \pm 1)$ in a one-dimensional lattice with periodic boundary conditions. The Hamiltonian is given by

$$H = -J \sum_{i=1}^{2N} s_i s_{i+1}$$

where J denotes the strength of the nearest-neighbour interactions with $J > 0$. Let F be the fully ferromagnetic state and let A be the lowest energy state with zero magnetization. The energy difference between these two states is

1. $\frac{3J}{2}$ 2. 4J 3. $\frac{J}{2}$ 4. $2J$

Q106. [June 2025] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2025 June	5M	Stat. Mech.

Two discrete time random walkers start from the point $x = 0$ at time $t = 0$ taking discrete steps of unit length along the x axis. The first walker is unbiased and the second walker is biased to move towards the right with probability p. The probability that they are at a distance of 2 units from each other at both time steps $t = 1$ and $t = 2$ is

1. $\frac{1}{4}$
2. $\frac{1}{2} - \frac{p}{2}$
3. $1 - \frac{3p}{4}$
4. $\frac{p}{2}$

Q107. [June 2025] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2025 June	5M	Stat. Mech.

A rigid molecule can have two possible rotational states: $j = 0$ or $j = 1$. Its rotational energies are given by $\epsilon_J = \frac{\hbar^2}{2I} j(j+1)$, where I is its moment of inertia. For an ensemble of such molecules in thermal equilibrium at temperature T, the ratio of the number of molecules in the $j = 1$ state (N_1), to those in $j = 0$ state (N_0), is $\frac{N_1}{N_0} = 0.003$. The temperature T (in units of $\frac{\hbar^2}{2Ik_B}$, where k_B is the Boltzmann constant) is closest to

1. 0.29
2. 0.21
3. 0.15
4. 0.34

Q108. [June 2025] . 5.0 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2025 June	5M	Stat. Mech.

A thermodynamic system (at temperature T and volume V), is described by its internal energy $U = AT^4V$ and pressure $p = \frac{1}{3}AT^4$, where A is a constant of appropriate dimension. The Helmholtz free energy of the system is

1. $\frac{4}{3}AT^4V$
2. $\frac{1}{3}AT^4V$
3. $-\frac{1}{3}AT^4V$
4. $-\frac{4}{3}AT^4V$

Answer Key

108 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Statistical Mechanics	Canonical Ensemble	**1**
Q2	Statistical Mechanics	Ising model	**4**
Q3	Statistical Mechanics	Canonical Ensemble	**4**
Q4	Statistical Mechanics	Canonical Ensemble	**1**
Q5	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q6	Statistical Mechanics	Microcanonical Ensemble	**4**
Q7	Statistical Mechanics	Canonical Ensemble	**4**
Q8	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**None**
Q9	Statistical Mechanics	Ising model	**1**
Q10	Statistical Mechanics	Quantum Statistical Mechanics	**3**
Q11	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q12	Statistical Mechanics	Microcanonical Ensemble	**3**
Q13	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q14	Statistical Mechanics	Canonical Ensemble	**2**
Q15	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**3**
Q16	Statistical Mechanics	Canonical Ensemble	**3**
Q17	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q18	Statistical Mechanics	Canonical Ensemble	**3**
Q19	Statistical Mechanics	Canonical Ensemble	**3**
Q20	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q21	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q22	Statistical Mechanics	Microcanonical Ensemble	**4**
Q23	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q24	Statistical Mechanics	Canonical Ensemble	**1**
Q25	Statistical Mechanics	Canonical Ensemble	**1**
Q26	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q27	Statistical Mechanics	Microcanonical Ensemble	**3**
Q28	Statistical Mechanics	Quantum Statistical Mechanics	**3**
Q29	Statistical Mechanics	Ising model	**4**
Q30	Statistical Mechanics	Microcanonical Ensemble	**1**
Q31	Statistical Mechanics	Canonical Ensemble	**4**
Q32	Statistical Mechanics	Canonical Ensemble	**1**
Q33	Statistical Mechanics	Grand Canonical ensemble	**1**
Q34	Statistical Mechanics	Ising model	**3**
Q35	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**3**
Q36	Statistical Mechanics	Canonical Ensemble	**4**
Q37	Statistical Mechanics	Microstates and Macrostates	**3**
Q38	Statistical Mechanics	Canonical Ensemble	**4**
Q39	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**1 or 3**
Q40	Statistical Mechanics	Black Body Radiations	**4**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q41	Statistical Mechanics	Canonical Ensemble	**2**
Q42	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q43	Statistical Mechanics	Microstates and Macrostates	**4**
Q44	Statistical Mechanics	Canonical Ensemble	**4**
Q45	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**2**
Q46	Statistical Mechanics	Canonical Ensemble	**1**
Q47	Statistical Mechanics	Canonical Ensemble	**4**
Q48	Statistical Mechanics	Microstates and Macrostates	**2**
Q49	Statistical Mechanics	Black Body Radiations	**3**
Q50	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**3**
Q51	Statistical Mechanics	Ising model	**2**
Q52	Statistical Mechanics	Black Body Radiations	**3**
Q53	Statistical Mechanics	Canonical Ensemble	**2**
Q54	Statistical Mechanics	Microstates and Macrostates	**4**
Q55	Statistical Mechanics	Black Body Radiations	**4**
Q56	Statistical Mechanics	Microcanonical Ensemble	**3**
Q57	Statistical Mechanics	Ising model	**2**
Q58	Statistical Mechanics	Black Body Radiations	**4**
Q59	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q60	Statistical Mechanics	Canonical Ensemble	**3**
Q61	Statistical Mechanics	Canonical Ensemble	**4**
Q62	Statistical Mechanics	Microcanonical Ensemble	**2**
Q63	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q64	Statistical Mechanics	Canonical Ensemble	**2**
Q65	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q66	Statistical Mechanics	Canonical Ensemble	**4**
Q67	Statistical Mechanics	Canonical Ensemble	**4**
Q68	Statistical Mechanics	Canonical Ensemble	**3**
Q69	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q70	Statistical Mechanics	Canonical Ensemble	**2**
Q71	Statistical Mechanics	Canonical Ensemble	**4**
Q72	Statistical Mechanics	Microstates and Macrostates	**4**
Q73	Statistical Mechanics	Microstates and Macrostates	**4**
Q74	Statistical Mechanics	Canonical Ensemble	**2**
Q75	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q76	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q77	Statistical Mechanics	Microcanonical Ensemble	**1**
Q78	Statistical Mechanics	Microstates and Macrostates	**2**
Q79	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q80	Statistical Mechanics	Microstates and Macrostates	**4**
Q81	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**3**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q82	Statistical Mechanics	Ising model	**1**
Q83	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q84	Statistical Mechanics	Canonical Ensemble	**2**
Q85	Statistical Mechanics	Black Body Radiations	**4**
Q86	Statistical Mechanics	Microcanonical Ensemble	**3**
Q87	Statistical Mechanics	Canonical Ensemble	**4**
Q88	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q89	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q90	Statistical Mechanics	Ising model	**4**
Q91	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q92	Statistical Mechanics	Canonical Ensemble	**1**
Q93	Statistical Mechanics	Canonical Ensemble	**2**
Q94	Statistical Mechanics	Microcanonical Ensemble	**4**
Q95	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**1**
Q96	Statistical Mechanics	Ising model	**4**
Q97	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**3**
Q98	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q99	Statistical Mechanics	Canonical Ensemble	**4**
Q100	Statistical Mechanics	Ising model	**1**
Q101	Statistical Mechanics	Canonical Ensemble	**1**
Q102	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q103	Statistical Mechanics	Microstates and Macrostates	**3**
Q104	Statistical Mechanics	Microcanonical Ensemble	**1**
Q105	Statistical Mechanics	Ising model	**2**
Q106	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**1**
Q107	Statistical Mechanics	Canonical Ensemble	**1**
Q108	Statistical Mechanics	Canonical Ensemble	**3**

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