Quantum Stastistics CSIR

https://snboseplc.com/quantum-statistics-csir/

CSIR Questions

Q.No:1 CSIR Dec-2014

An ideal Bose gas is confined inside a container that is connected to a particle reservoir. Each particle can occupy a discrete set of single-particle quantum states. If the probability that a particular quantum state is unoccupied is 0.1, then the average number of bosons in that state is

1. 8
2. 9
3. 10
4. 11

Q.No:2 CSIR June-2015

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

$$N_e = c\int_0^\infty \frac{\epsilon^{(d-s)/s}}{e^{\beta(\epsilon-\mu)}-1}\,d\epsilon$$

where c is a constant, should remain finite even for $\mu = 0$. This can happen if

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

Q.No:3 CSIR June-2015

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

Q.No:4 CSIR Dec-2015

A thin metal film of dimension 2 mm$\times$2 mm contains 4×10^{12} electrons. The magnitude of the Fermi wavevector of the system, in the free electron approximation, is

1. $2\sqrt{\pi}\times 10^7$ cm^{-1}
2. $\sqrt{2\pi}\times 10^7$ cm^{-1}
3. $\sqrt{\pi}\times 10^7$ cm^{-1}
4. $2\pi\times 10^7$ cm^{-1}

Q.No:5 CSIR June-2016

Suppose the frequency of phonons in a one-dimensional chain of atoms is proportional to the wavevector. If n is the number density of atoms and c is the speed of the phonons, then the Debye frequency is

1. $2\pi cn$
2. $\sqrt{2\pi cn}$
3. $\sqrt{3\pi cn}$
4. $\pi cn/2$

Q.No:6 CSIR June-2016

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

Q.No:7 CSIR Dec-2016

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

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Q.No:8 CSIR June-2017

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

Q.No:9 CSIR June-2017

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

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

Q.No:10 CSIR Dec-2017

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

Q.No:11 CSIR Dec-2017

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}

Q.No:12 CSIR Dec-2017

A metallic nanowire of length l is approximated as a one-dimensional lattice of N atoms with lattice spacing a. If the dispersion of electrons in the lattice is given as $E(k) = E_0 - 2t\cos(ka)$, where E_0 and t are constants, then the density of states inside the nanowire depends on E as

1. $N^3\sqrt{\dfrac{t^2}{E-E_0}}$
2. $\sqrt{\left(\dfrac{E-E_0}{2t}\right)^2 - 1}$
3. $N^3\sqrt{\dfrac{E-E_0}{t^2}}$
4. $\dfrac{N}{\sqrt{(2t)^2-(E-E_0)^2}}$

Q.No:13 CSIR June-2018

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

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

Q.No:14 CSIR Dec-2018

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

Q.No:15 CSIR Dec-2018

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. $\bar{n}(1-\bar{n})$

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

Q.No:16 CSIR Dec-2018

At low temperatures, in the Debye approximation, the contribution of the phonons to the heat capacity of a two-dimensional solid is proportional to

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

Q.No:17 CSIR Dec-2018

The dispersion relation of optical phonons in a cubic crystal is given by $\omega(k) = \omega_0 - ak^2$, where ω_0 and a are positive constants. The contribution to the density of states due to these phonons with frequencies just below ω_0 is proportional to

1. $(\omega_0 - \omega)^{1/2}$
2. $(\omega_0 - \omega)^{3/2}$
3. $(\omega_0 - \omega)^2$
4. $(\omega_0 - \omega)$

Q.No:18 CSIR Dec-2019

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

Q.No:19 CSIR Dec-2019

For T much less than the Debye temperature of copper, the temperature dependence of the specific heat at constant volume of copper, is given by (in the following a and b are positive constants)

1. aT^3
2. $aT + bT^3$
3. $aT^2 + bT^3$
4. $\exp\left(-\frac{a}{k_B T}\right)$

Q.No:20 Assam CSIR Dec-2019

Two spheres are subjected to black-body radiation at temperatures T_1 and T_2 respectively. For the first sphere only half of its surface is exposed to the radiation, while the full surface of the second sphere is exposed. The ratio of the radii of the spheres are $R_1/R_2 = 2$. If the forces due to radiation pressure on the two spheres are the same, the ratio T_1/T_2 is

1. $2^{1/4}$
2. $1/\sqrt{2}$
3. 1
4. $1/2^{1/4}$

Q.No:21 CSIR June-2020

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

Q.No:22 CSIR June-2020

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 $4m$

Q.No:23 CSIR Feb-2022

The volume and temperature of a spherical cavity filled with black body radiation are V and $300K$, 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

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Q.No:24 CSIR Feb-2022

The total number of phonon modes in a solid of volume V is $\int_0^{\omega_D} g(\omega)\, d\omega = 3N$, is the number of primitive cells, ω_D is the Debye frequency and density of photon modes is $g(\omega) = AV\omega^2$ (with $A > 0$ a constant). If the density of the solid doubles in a phase transition, the Debye temperature Θ_D will

1. increase by a factor of $2^{2/3}$
2. increase by a factor of $2^{1/3}$
3. decrease by a factor of $2^{2/3}$
4. decrease by a factor of $2^{1/3}$

Q.No:25 CSIR Feb-2022

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

Q.No:26 CSIR Sep-2022

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

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

Q.No:27 CSIR June-2023

The single particle energies of a system of N non-interacting fermions of spin s (at $T = 0$) are $E_n = n^2E_0$, $n = 1, 2, 3, \ldots$. The ratio $\epsilon_F(3/2)/\epsilon_F(1/2)$ 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

Q.No:28 CSIR June-2023

The energy levels available to each electron in a system of N non-interacting electrons are $E_n = nE_0$, $n = 0, 1, 2, \ldots$. 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. $\dfrac{1}{2}N^2E_0$
2. N^2E_0
3. $\dfrac{1}{8}N^2E_0$
4. $\dfrac{1}{4}N^2E_0$

Q.No:29 CSIR June-2023

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. $T^{3/2}$

Q.No:30 CSIR June-2023

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

Q.No:31 CSIR June-2023

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. $\dfrac{e^{-3\beta J/4}}{3e^{\beta J/4} + e^{-3\beta J/4} + 2e^{-10\beta J}}$

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2. $\frac{3e^{-\beta J/4}}{3e^{-\beta J/4}+e^{3\beta J/4}+2e^{-10\beta J}}$

3. $\frac{e^{-\beta J/4}}{2e^{-\beta J/4}+3e^{3\beta J/4}+2e^{-10\beta J}}$

4. $\frac{3e^{-3\beta J/4}}{2e^{\beta J/4}+3e^{-3\beta J/4}+2e^{-10\beta J}}$

Q.No:32 CSIR Dec-2023

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. ${}^MC_R$

Q.No:33 CSIR Dec-2023

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

Q.No:34 CSIR Dec-2023

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

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

Q.No:35 CSIR June-2024

The Debye temperature of a two-dimensional insulator is $150\,K$. The ratio of the heat required to raise its temperature from $1\,K$ to $2\,K$ and from $2\,K$ to $3\,K$ is

1. 7 : 19
2. 3 : 13
3. 1 : 1
4. 3 : 5

Q.No:36 CSIR Dec-2024

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

Q.No:37 CSIR Dec-2024

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

Q.No:38 CSIR Dec-2024

Consider a free fermion gas in a hypercubic infinite potential well in hypothetical 4-dimensional space. What is the expression for the ground state energy per particle in terms of the Fermi energy E_F? (Ignore spin degeneracy of the fermions)

1. $\frac{4}{5}E_F$
2. $\frac{2}{3}E_F$

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3. $\frac{1}{3}E_F$
4. $\frac{2}{5}E_F$

Q.No:39 CSIR Dec-2024

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 $n_A = 1.80 \times 10^{14}\,\mathrm{cm}^{-3}$ and $n_B = 1.44 \times 10^{15}\,\mathrm{cm}^{-3}$, respectively. If P_A and P_B are the pressures of the two gas samples, the ratio $\frac{P_A}{P_B}$ is

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

Q.No:40 CSIR Dec-2025

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. $P_C > P_B > P_F$

Q.No:41 CSIR Dec-2025

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 neighbouring atoms cannot both be in the e state. The partition function of this system at temperature T, is

1. $1 + 5e^{-E/(k_BT)} + 2e^{-2E/(k_BT)}$
2. $1 + 5e^{-E/(k_BT)} + 3e^{-2E/(k_BT)}$
3. $1 + 5e^{-E/(k_BT)} + 10e^{-2E/(k_BT)}$
4. $1 + 5e^{-E/(k_BT)} + 5e^{-2E/(k_BT)}$

Q.No:42 CSIR Dec-2025

In a one-dimensional chain of atoms, the phonon energy dispersion is given by $E = A|\sin ka|$. Here, A is a constant, k is a vector in the reciprocal space and a is lattice spacing. The density of states is proportional to

1. $\frac{1}{\sqrt{A^2-E^2}}$
2. $\frac{1}{\sqrt{A^2+E^2}}$
3. $\frac{1}{\sqrt{A-E}}$
4. $\frac{1}{\sqrt{A+E}}$

Q.No:43 CSIR Dec-2025

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 ($k_BT \gg J$) is

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

Q.No:44 CSIR Dec-2025

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

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Q.No:45 CSIR June-2026

Two particles occupy ten degenerate energy levels. There are three possible scenarios where the two particles are either identical bosons or identical fermions or distinguishable particles, with the associated number of accessible microstates denoted as Ω_B, Ω_F and Ω_C, respectively. Then, which of the following options is correct?

1. $\Omega_B = 55,\ \Omega_F = 45,\ \Omega_C = 100$
2. $\Omega_B = 65,\ \Omega_F = 55,\ \Omega_C = 100$
3. $\Omega_B = 45,\ \Omega_F = 25,\ \Omega_C = 55$
4. $\Omega_B = 55,\ \Omega_F = 45,\ \Omega_C = 75$

Q.No:46 CSIR June-2026

There is a ferromagnetic interaction J between two Ising spins, $S_1, S_2 = \pm 1$, and they are under the influence of an external magnetic field h. The Hamiltonian of this system is

$$H = -JS_1S_2 - hS_1 - hS_2.$$

The spins are in equilibrium at temperature T and $\beta = 1/k_BT$ with k_B as Boltzmann constant. The average value of either spin, for small h, is:

1. $\dfrac{4h\exp(\beta J)}{\cosh(\beta J)}$
2. $\dfrac{h\exp(2\beta J)}{\cos(\beta J)}$
3. $\dfrac{8h\exp(4\beta J)}{\sinh(\beta J)}$
4. $\dfrac{2h\exp(2\beta J)}{\sin(\beta J)}$

Question No.	**Entrance with year**	answer
Q1	CSIR-Dec-2014	Option 2
Q2	CSIR-June-2015	Option 3
Q3	CSIR-June-2015	Option 1
Q4	CSIR-Dec-2015	Option 2
Q5	CSIR-June-2016	Option 1
Q6	CSIR-June-2016	Option 1
Q7	CSIR-Dec-2016	Option 1
Q8	CSIR-June-2017	Option 2
Q9	CSIR-June-2017	Option 3
Q10	CSIR-Dec-2017	Option 4
Q11	CSIR-Dec-2017	Option 2
Q12	CSIR-Dec-2017	Option 4
Q13	CSIR-June-2018	Option 3
Q14	CSIR-Dec-2018	Option 1
Q15	CSIR-Dec-2018	Option 1
Q16	CSIR-Dec-2018	Option 1
Q17	CSIR-Dec-2018	Option 1
Q18	CSIR-Dec-2019	Option 1
Q19	CSIR-Dec-2019	Option 2
Q20	Assam-CSIR-Dec-2019	Option 4
Q21	CSIR-June-2020	Option c
Q22	CSIR-June-2020	Option d
Q23	CSIR-Feb-2022	Option 4
Q24	CSIR-Feb-2022	Option 2
Q25	CSIR-Feb-2022	Option 1
Q26	CSIR-Sep-2022	Option 4
Q27	CSIR-June-2023	Option 2
Q28	CSIR-June-2023	Option 4
Q29	CSIR-June-2023	Option 1
Q30	CSIR-June-2023	Option 1
Q31	CSIR-June-2023	Option 2
Q32	CSIR-Dec-2023	Option 4
Q33	CSIR-Dec-2023	Option 4
Q34	CSIR-Dec-2023	Option 4
Q35	CSIR-June-2024	Option 1
Q36	CSIR-Dec-2024	Option 2
Q37	CSIR-Dec-2024	Option 4
Q38	CSIR-Dec-2024	Option 2
Q39	CSIR-Dec-2024	Option 1
Q40	CSIR-Dec-2025	Option 2
Q41	CSIR-Dec-2025	Option 4
Q42	CSIR-Dec-2025	Option 1
Q43	CSIR-Dec-2025	Option 1
Q44	CSIR-Dec-2025	Option 2
Q45	CSIR-June-2026	Option 1
Q46	CSIR-June-2026	NA

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