PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

Quantum Statistical Mechanics - CSIR NET Physics PYQs

Statistical Mechanics . All PYQs (2015-2025) with answer key

19 questions . Answer key included

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Q1. [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. $\frac{1}{2} < \frac{d}{s} < 1$

Q2. [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. $\mathrm{E}^{3/2}$
3. $\mathrm{E}^{1/2}$
4. E^{2}

Q3. [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}

Q4. [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. $\varepsilon_F \propto \rho^{1/3}$

Q5. [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. $\frac{\epsilon_F^2}{(2\pi v^2\hbar^2)}$

Q6. [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}

Q7. [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

Q8. [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

Q9. [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

Q10. [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

Q11. [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. $\frac{7}{6}Nk_B$
2. $\frac{4}{3}Nk_B$
3. $\frac{3}{2}Nk_B$
4. $\frac{2}{3}Nk_B$

Q12. [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

Q13. [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. $T^{3/2}$

Q14. [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

Q15. [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

Q16. [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

Q17. [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. $\frac{\pi^2\hbar^2}{4mr_0^5}$

Q18. [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. $P_c > P_B > P_F$.

Q19. [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. $T^{\frac{1}{2}}$

Answer Key

19 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Statistical Mechanics	Quantum Statistical Mechanics	**3**
Q2	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q3	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q4	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q5	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q6	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q7	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q8	Statistical Mechanics	Quantum Statistical Mechanics	**3**
Q9	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q10	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q11	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q12	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q13	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q14	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q15	Statistical Mechanics	Quantum Statistical Mechanics	**2**
Q16	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q17	Statistical Mechanics	Quantum Statistical Mechanics	**1**
Q18	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q19	Statistical Mechanics	Quantum Statistical Mechanics	**2**

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