St. Philomena's College (Autonomous), Mysore
Question Bank

Programme: M.Sc. Physics
I Semester

Course Title: Thermodynamics and Statistical Physics
Course Type: Hard Core
Q.P Code:

Q No.	Question	Marks
1	State and explain the second law of thermodynamics.	4
2	Give the mathematical definitions of first and second law of thermodynamics.	4
3	State and explain the second law of thermodynamics in terms of the change in entropy and heat energy at a given temperature T.	4
4	Mention any two thermodynamic potentials. How are these related to the thermodynamic variables S, T, P and V? Explain	4
5	Prove that the isothermal compressibility coefficient (KT) of any thermodynamic system does not approach zero as $T \rightarrow 0K$.	4
6	State and explain the Nernst formulation of the third law of thermodynamics.	4
7	Explain the terms 'phase' and 'phase transition'.	4
8	Explain the effect of pressure on the melting point of a solid.	4
9	Explain the terms microstates and macrostates for a statistical system of N number of particles.	4
10	Explain the condition for statistical equilibrium associated with a statistical system.	4
11	State and explain any two basic postulates of Bose-Einstein Statistics.	4
12	Plot a graph of the Fermi distribution function as a function of energy at absolute zero of temperature. Define Fermi energy from the graph.	4
13	What are thermodynamic potentials ? How are they related to thermodynamic variables S,T,P and V? Explain.	6
14	Show that the ratio of adiabatic to isobaric expansion coefficients is $\frac{\alpha_s}{\alpha_T} = \frac{C_V}{C_V - C_P}$ equal to	6
15	Using Maxwell thermodynamic relations show that for a fluid $\left(\frac{\partial C_V}{\partial V}\right)_T = T\left(\frac{\partial^2 P}{\partial T^2}\right)_V$ of one component system:	6

16	Show that for a gas obeying the relation PV = RT + BP, $\left(C_P - C_V\right) = R + 2P\left(\frac{\partial B}{\partial T}\right)$	6
17	Using Maxwell thermodynamic relations show that for a fluid $\left(\frac{\partial C_V}{\partial V}\right)_T = T\left(\frac{\partial^2 P}{\partial T^2}\right)_V$ of one component system	6
18	State and explain the third law of thermodynamics.	6
19	Define the coefficient of thermal expansion and isothermal $\left(\frac{\partial P}{\partial T}\right)_V = \frac{\alpha}{K_T}$ compressibility K_T in terms of the state variables and hence show that:	6
20	Describe the phase diagram of water (H_2O).	6
21	Explain with necessary diagrams the first and second order phase transitions.	6
22	Explain under what condition a real gas approach ideal behaviour?	6
23	In a schematic way, show the isotherms for a liquid-gas transition in the V-P plane for temperatures T_1, T_2, T_3, T_C, T_4, T_5 such that $T_1 < T_2 < T_3 < T_C < T_4 < T_5$, where T_C is the critical point temperature.	6
24	Explain the merits and demerits of Van der Waals equation of state.	6
25	Describe, briefly what is meant by phase space.	6
26	State and explain the postulates of a priori probability.	6
27	Find the number of ways of realizing heads in the simultaneous tossing of 3 coins.	6
28	Define what is phase space and explain how it leads to μ-space and Γ-space of a system.	6
29	State and explain Ergodic hypothesis.	6
30	Define what is phase space and explain how it leads to μ-space and Γ-space of a system.	6
31	State and explain the postulates of a priori probability.	6
32	State and explain Ergodic hypothesis.	6
33	Distinguish among microcanonical, canonical and grand canonical ensembles.	6
34	Consider 2 particles A and B in a container which is divided into 2 equal halves. Calculate the probability of finding particles A and B in the left half and right half of the container.	6
35	Given two particles and three cells. How do you arrange them in various energy states according Maxwell-Boltzmann Statistics? Explain by preparing a suitable table.	6
36	Justify the Stirling's approximation for ln(N!) by the graphical method.	6

37	Using the expression for partition function arrive at an expression for total energy of a system containing N-atoms per unit volume, in the form E(total) = $NkT^2 \frac{d(\ln Z)}{dT}$.	6
38	Using equipartition theorem show that the ratio of two specific heats of monoatomic gas γ=1.66.	6
39	State and explain Boltzmann equipartition theorem.	6
40	State the law of equipartition theorem and hence show that the ratio of the specific heats for a polyatomic gas is 1.33.	6
41	State the two basic postulates of quantum statistics.	6
42	Express Bose-Einstein distribution formula in its differential form.	6
43	Define Bose-Einstein distribution function. Represent this function graphically as a function of energy and show that the distribution reduces to the classical Maxwell-Boltzmann distribution function at high temperatures.	6
44	Discuss the criteria for indistinguishability of identical particles.	6
45	Given two particles and three energy cells. How do you arrange them in various energy states according to Bose-Einstein statistics? Explain with a necessary Table.	6
46	Express Bose-Einstein distribution formula in the differential form.	6
47	State and explain the symmetry requirements for a quantum mechanical description of identical particles.	6
48	Describe with examples symmetric and antisymmetric wave function for a system of particles.	6
49	Given two particles and three energy cells. How do you arrange them in various energy states according to Fermi-Dirac statistics? Explain with a necessary Table.	6
50	Describe with examples symmetric and antisymmetric wave function for a system of particles.	6
51	Define Fermi distribution function. Sketch the Fermi distribution function as a function of energy and show that the Fermi distribution reduces to the classical distribution at high temperatures and also it becomes a discontinuous step function at T = 0K.	6
52	Bring out the difference between Bose-Einstein and Fermi- Dirac statistics.	6
53	Using the distribution function derived in the differential form for an ideal Bose gas (i) explain Bose-Einstein condensation and (ii) obtain an expression for the transition temperature T_B below which Bose condensation occurs.	6+6
54	Calculate the Fermi energy of an electron gas in Cu. Given: $m_e = 9.1 \times 10^{-27}$g, density of electron gas = (N/V) = 8.4×10^{23}/cc and h = 6.625×10^{-27} ergs-sec.	6
55	The atomic weight of lithium is 6.94 and its density is 0.538g/cc. Calculate the Fermi energy of lithium in units of eV.	6
56	Show that the Wien's law is the limiting case of Planck's law of black body radiation.	6

57 Show that Rayleigh-Jeans law is the limiting case of Planck's law of black body radiation. 6

58 Express the potential functions 8

$$(i)\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P \ and \ (ii)\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$

enthalpy H(S,P) and Gibbs free energy G(P,T) in their differential forms and show that these functions respectively lead to the relations

59 Using the potential functions E(S,V) 8

$$(i)\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V \ and \ (ii)\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

and F(V,T) obtain the following two Maxwell thermodynamics relations:

60 Arrive at the following relations 8

$$(i)\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V \ and \ (ii)\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

using Internal energy E(S,V) and Enthalpy H(S,P) functions:

61 Express the potential functions 8

$$(i)\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V \ and \ (ii)\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$

Internal energy E(S,V) and Gibbs free energy G(P,T) in their differential forms and show that these functions respectively lead to the following relations:

62 Explain, with examples, the characteristics of first order and second order phase transitions. 8

63 Describe the thermodynamic classification of I and II order phase transitions. 8

64 Using Van der Waals equation of state, explain the observed variations of P with respect to V at different temperatures, in the case of CO_2. 8

65 Explain the merits and demerits of Van der Waals equation of state. 8

66 Explain under what condition a real gas approaches ideal behaviour. 8

67 Obtain the general expression for thermodynamic probability and hence define the most probable distribution associated with a classical system containing N number of particles per unit volume. 8

68 Obtain the expression for the most probable distribution associated with a system of N identical and distinguishable particles. 8

69 Derive the partition function for a monoatomic gaseous system at a temperature T. 8

70 Discuss the criteria for distinguishability of identical particles. 8

71 Explain with relevant theory, the condition under which Fermi-Dirac Statistics 8

reduces to Maxwell-Boltzmann Statistics.

72 Give the important features of M-B, B-E and F-D statistics. 8

73 Obtain the Wien's law and Rayleigh-Jeans law as limiting cases of Planck's law 8

74 Derive an expression for the partition function of a monoatomic gas containing N number of atoms per unit volume. 9

75 Obtain an expression for the partition function of a system of N diatomic molecules executing only the rotational motion. 9

76 Show that the (i) specific heats Cp and Cv and (ii) volume expansion co-efficient (α_p) of any thermodynamics systems tend to zero as the temperature approaches zero degree Kelvin. 10

77 Discuss with relevant theory the conditions under which two phases of an one component system are in the state of thermodynamic equilibrium. 10

78 For a system exhibiting solid and liquid phases 10

$$\left(\frac{dP}{dT}\right) = \frac{L}{T\left(V_{solid} - V_{liquid}\right)}$$

simultaneously at a given temperature, show that:

79 Derive Clausius-Clapeyron equation with the help of Maxwell thermodynamic relation and explain the effect of pressure on the boiling points of liquids. 10

80 Obtain Einstein's relation for diatomic molecules. 10

81 Show that for a gas at very low temperatures T the number of particles in the ground state is given as $n_0 = N\left[1 - \left(\frac{T}{T_B}\right)^{3/2}\right]$, N is the number of particles per unit volume of the gas and T_B is the Bose condensation temperature. 10

82 On the basis of Bose-Einstein statistics derive Planck's law for the distribution of energy with wavelength λ in the black body radiation spectrum. 10

83 Using the thermodynamic potential functions: E, H, F and G obtain the four Maxwell thermodynamic relations. 12

84 Describe any three important consequences of the third law of thermodynamics. 12

85 State the third law of thermodynamics and discuss any three important consequences of the third law of thermodynamics. 12

86 Give a detailed account of thermodynamics of phase transitions for a pure substance. 12

87 Discuss with necessary theory the general conditions for phase equilibrium. 12

88 Derive Clausius-Clapeyron equation for a system exhibiting transition from its liquid to vapour phase. 12

89 Discuss the behaviour of Van der Waals equation of state for imperfect gases as observed in Andrew's experiment. 12

90	Prove Liouville's theorem that $\rho(t,q_k,p_k)$ is a constant along every phase trajectory of the system in the Γ - space.	12
91	State and prove Liouville's theorem.	12
92	Obtain the Boltzmann distribution law at thermal equilibrium for an isolated system of n-distinguishable particles capable of occupying non-degenerate levels E_i, using Lagrange method of undetermined multipliers.	12
93	Define partition function and derive an expression for mean energy and specific heat of a system containing N atoms per unit volume in terms of partition function.	12
94	Treating the ideal gas as a system governed by classical statistics, derive the Maxwell-Boltzmann distribution formula $n_i = \frac{1}{e^{(\alpha + \beta E_i)}}$.	12
95	Derive the expression for translational partition function for an ideal monoatomic gas and hence show that for this gas the total energy E(total) = 3/2 (NkT).	12
96	Derive an expression for the partition function for a system of N diatomic molecules executing only the rotational motion and hence show that the total energy E(total) = (NkT).	12
97	Derive the expression for the rotational partition function and hence obtain the expressions for total energy and specific heat for a system containing N diatomic molecules per unit volume.	12
98	Derive an expression for the most probable distribution of bosons which obey Bose-Einstein statistics.	12
99	Derive the Bose-Einstein distribution formula for a system of n bosons occupying a set of energy levels E_i at thermal equilibrium.	12
100	Derive the Fermi-Dirac distribution formula for a gas of non-interacting Fermions at a temperature T.	12
101	Deduce the expression for quantum distribution for a system of Fermions.	12
102	Explain what is Bose-Einstein condensation and obtain an expression for the particle density in the ground state in terms of the condensation temperature T_B.	12
103	Using Bose-Einstein distribution formula derive Planck's formula for spectral energy distribution of black body radiation.	12
104	Derive the black body radiation formula through Planck's semi-classical approach.	12