EPL-204: Thermal and Statistical Physics

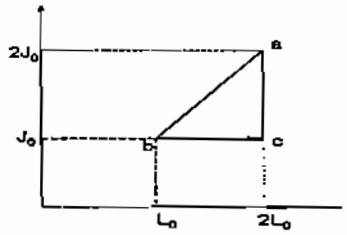
Major Test

Duration: 2 hours Max. marks :50

1 (a). Compute the efficiency of a heat engine shown in the figure below. The engine uses a rubber band whose equation of state is

$$J = \alpha LT$$

where α is a constant, J is the tension, L is the length per unit mass, and T is the temperature in Kelvins. The specific heat (heat capacity per unit mass) is a constant, $C_L = C$.



[3]

(b) In a process transfer of heat (Q) occurs through a medium from hotter (temperature T_1) to a cooler reservoir (temperature T_2). Obtain the change of entropy of the system, local surrounding and the change of entropy of the universe.

[3]

(c) An idcal gas is composed of N "red" atoms of mass m, N "blue" atoms of mass m and N "green" atoms of mass m (total 3N atoms). Atoms of same colour are indistinguishable and atoms of different colours are distinguishable. The gas is in contact with a thermal bath. Find the partition function of the gas.

[3]

2. (a) Following statement is True or False?

(i) Boson gas will exert more pressure on the wall of container as compared to Fermion gas.

(ii) At very large temperature behaviour of a paramagnet and ferromagnet will be similar.

(iii) Dissolution of a sugar in water is an example of physical irreversibility.

(iv) Phenomena of superfluidity can be explained very well only in the framework of Bose-Einstein condensation. [2]

(b) Draw the following

(i) Typical variation of C_P and C_V with temperature as temperature approaches to zero.

(ii) Typical variation of specific heat of a metal with temperature from 2K to 400K. In different temperature ranges [300-400K, 50-100K, 2-10K] indicate how specific heat varies with temperature assuming Einstein's temperature is 200K.

(iii) Variation of specific heat of liquid Helium in the temperature range of 1K to 4K.

[2+4+2]

3. (a) For an asymmetric coin, head occurs 3 times as often as tail. Write the expression for the probability of occurance of (i) 4 times tail if the coin is tossed 8 time, (ii) 40 times tail if coin is tossed 500 times. [3]

(b) Consider a random walk in one dimension for which the walker at each step is equally likely to take a step with displacement anywhere in the interval $d-a \le x \le d+a$, where $a<d$. Each step is independent of others. After N steps the displacement of the walker is $S=X_1+X_2+.....+X_N$ where X_i is the displacement after ith step. After N steps, what is the average displacement ⟨S⟩, of the walker ? [3]

(c) What happens if

(i) for a throttling process, temperature is smaller than the inversion temperature.

(ii) the temperature of ^{4}He is less than lambda point.

(iii) temperature for a 2D Ising spin arrangement is less than the critical temperature.

(iv) temperature of electron gas is much above the Fermi temperature. [4]

4 (a) For one dimensional Ising chain of N spins (N is very large) show that the entropy is expressed as

$$S = Nk\left[\ln\left(e^{2\beta J}+1\right)-\frac{2\beta J}{1+e^{-2\beta J}}\right] \qquad [3]$$

(b) Is it true to say that Ising one dimensional chain do not show phase transition? [1]

(c) How the occurrence of superfluidity is observed in ^{4}He. Write three distinguished properties of superfluid. Why the superfluidity temperature of ^{3}He is smaller than that of ^{4}He. [3]

(d) How laser cooling occurs? What is its use in Bose Einstein condensation? [2]

5. (a) Consider a gas of identical particles in a volume V which is in equilibrium at the temperature T. If the partieles are Fermions, obtain an expression of the average number of particles in s state ($\bar{n}_s$) in terms of energy of s^{th} state (ε_S) and chemical potential (μ). [3]

(b) For a monotatomic gas of N identical particles of mass m in a container of volume V at temperature T, obtain expression of partion function when we are also including the interaction between particles. [3]

(c) For Maxwell velocity distribution show that avcrage velocituy is zero. [2]

6. Describe the following ⟨only two/three lines)

(a) Landau potential

(b) Grand Canonical ensemble

(c) Ergodic hypothesis

⟨d) Liouville theorem [4]