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MANIPAL UNIVERSITY

Deemed- to -be -University under Section 3 of the UGC Act, 1956

DEPARTMENT OF SCIENCES, M.Sc (P/C/M/G)

FOURTH SEMESTER M.SC (PHYSICS) END SEMESTER EXAMINATION, APRIL 2017

SUB: THERMODYNAMICS AND STATISTICAL PHYSICS (PHY- 702)

(REVISED CREDIT SYSTEM)

TIME: 3 HRS. DATE: 20-04-2017 **MAX.MARKS : 50**

NOTE:(A) ANSWER ANY FIVE FULL QUESTIONS. (B) EACH QUESTION CARRIES 10 MARKS.

1A. Obtain the differential expressions for the following thermodynamic variables: temperature in terms of internal energy, pressure in terms of internal energy, temperature in terms of enthalpy, volume in terms of enthalpy, entropy in terms of Helmholtz free energy, pressure in terms of Helmholtz free energy. **[6]**

1B. Obtain the Gibbs-Helmholtz relations. **[4]**

2A. Prove the following for a van der Waals gas:
$\text{difference in molar heat capacities} = n\,R\left(1 + \frac{\mathbf{2\,a\,n}}{\mathbf{R\,T\,V}}\right)$
where R = gas constant, T = temperature, V = volume,
n = number of moles of the gas, a = van der Waals constant. **[5]**

2B. Use van der Waals equation of state to obtain an expression for Joule-Thomson coefficient of a real gas. Also obtain an expression for the inversion temperature. **[5]**

3A. Define chemical potential. Obtain expressions for chemical potential in terms of entropy, Helmholtz free energy, Gibbs free energy. **[5]**

3B. Obtain an expression for rotational contribution to heat capacity of a gas of diatomic molecules. **[5]**

4A. At $T = T_C$, $\left(\frac{\partial P}{\partial V}\right)_{T_C} = 0$, $\left(\frac{\partial^2 P}{\partial V^2}\right)_{T_C} = 0$. Determine a and b in the van der Waals equation of state in terms of T_C and P_C. **[5]**

4B. Obtain the expressions for the thermodynamic quantities [entropy, pressure, number of particles, internal energy] of a grand canonical ensemble in terms of grand partition function. **[5]**

5A. Show that for a grand canonical ensemble of a perfect gas, the probability of finding a subsystem of N-atoms is given by Poisson distribution: $\omega(N) = \frac{1}{N!}(\bar{N})^N \exp(-\bar{N})$.**[5]**

5B. Show that the number of photons in a black body radiation at a temperature T is
$N = \frac{V}{\pi^2}\left(\frac{kT}{\hbar c}\right)^3 \int_0^\infty \frac{x^2\,dx}{e^x - 1}$, where V = volume of the cavity, $x = \frac{h\nu}{kT}$. **[5]**

6A. Derive Fick's second law by recognizing that the time rate of composition change in the unit area slab is equal to the difference between the flux into the slab, $\mathrm{J(x)}$, and the flux out of the slab, $\mathrm{J(x+dx)}$, and also that $\mathrm{J(x+dx) = J(x)} + \left(\frac{\partial \mathrm{J}}{\partial \mathrm{x}}\right)\Delta \mathrm{x}$. **[5]**

6B. Show that during the first order phase transition, the Gibbs function is continuous, but the first order derivatives of the Gibbs function change discontinuously. **[5]**

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Useful formulae:

Stirling formula: $n! \cong (2\pi n)^{1/2} n^n e^{-n}$

$$\ell n(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \cdots \quad , \quad |x| < 1$$

$$e^x = \sum_{o}^{\infty} \frac{x^n}{n!}$$

$$\int_o^\infty x^r e^{-nx} \, dx = \frac{r!}{n^{r+1}}$$

$$\int_o^\infty x^4 \, exp \, (-ax^2) \, dx = \frac{3}{8a^2}\sqrt{\frac{\pi}{a}}$$

$$\int_o^\infty x^2 \, exp \, (-ax^2) \, dx = \frac{1}{4a}\sqrt{\frac{\pi}{a}}$$

$$\int_o^\infty \frac{x^{n+1}}{e^x - 1} \, dx = \Gamma(n)\,\zeta(n)$$

$\Gamma(n+1) = n!$ if n is an integer

$\Gamma(n+1) = n(n-1)\cdots\frac{3}{2}\cdot\frac{1}{2}\cdot\sqrt{\pi}$ if n is half integral

$$\zeta(4) = \frac{\pi^4}{90}$$

$$\zeta\left(\frac{5}{2}\right) = 1.341$$

$$\zeta\left(\frac{3}{2}\right) = 2.612$$

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