BPHCT-135

ASSIGNMENT BOOKLET

BACHELOR'S DEGREE PROGRAMME
(B.SC.G)

THERMAL PHYSICS AND STATISTICAL MECHANICS

Valid from 1st January, 2023 to 31st December, 2023

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2023)

Dear Student,

Please read the section on assignments in the Programme Guide for B. Sc. that we sent you after your enrolment. A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet, and it consists of two parts, Part A and B. The total marks of all the parts are 100, of which 35% are needed to pass it.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

ROLL NO.: ……

NAME: ……

ADDRESS: ……

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COURSE CODE:…….

COURSE TITLE: ……

ASSIGNMENT CODE: ……..

STUDY CENTRE: …….. **DATE:** ……..……...

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.
3) Leave 4 cm margin on the left, top and bottom of your answer sheet.
4) Your answers should be precise.
5) Solve Part A and Part B of this assignment, and **submit the complete assignment answer sheets containing Parts A and B within the due date.**
6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date shall not be accepted.**

   We strongly suggest that you retain a copy of your answer sheets.
7) This assignment is **valid from 1st January, 2023 to 31st December, 2023**. If you have failed in this assignment or fail to submit it by 31st December, 2023, then you need to get the assignment for the year 2024, and submit it as per the instructions given in the Programme Guide.
8) **You cannot fill the examination form for this course** until you have submitted this assignment. For any queries, please contact: drsgupta@ignou.ac.in, slamba@ignou.ac.in. We wish you good luck.

Tutor Marked Assignment
THERMAL PHYSICS AND STATISTICAL MECHANICS

Course Code: BPHCT-135
Assignment Code: BPHCT-135/TMA/2023
Max. Marks: 100

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) Calculate the temperature at which root mean square speed of nitrogen molecules exceeds their most probable speed by $200\ \text{ms}^{-1}$. Take $m_{N_2} = 28\ \text{kg kmol}^{-1}$. (5)

   b) Using the relation

   $$dN_v = 4\pi N\left(\frac{m}{2\pi k_B T}\right)^{3/2} v^2 \exp\left[-\left(\frac{mv^2}{2k_B T}\right)\right]dv$$

   for the number of molecules in a Maxwellian gas having speeds in the range v to $v + dv$, obtain an expression for (i) average speed, and (ii) root mean square speed. (5)

   c) Derive the survival equation for distribution of free paths. Hence, plot distribution of free paths as a function of $\frac{x}{\lambda}$. (4+1)

   d) Calculate the diffusion coefficient of hydrogen molecules at 27°C when pressure is 3 atm. Assume that it behaves as a Maxwellian gas. Take $r_{H_2} = 1.37\times10^{-10}\text{m}$ and $k_B = 1.38\times10^{-23}\text{JK}^{-1}$. (5)

   e) Define Brownian motion. Write its four observed characteristics. (1+4)

2. a) What do you understand by (i) isobaric (ii) isochoric (iii) isothermal, and (iv) cyclic processes? Represent these processes on p-V diagrams. (2+3)

   b) Prove that for a pVT-system

   $$\frac{dV}{V} = \alpha dT - \beta_T dp$$

   where α is the isobaric coefficient of volume expansion and β_T is isothermal compressibility. (5)

   c) Write the differential form of first law of thermodynamics. Show that for an ideal gas, it can be written as $\delta Q = C_V dT + pdV$. Using this result for one mole of an ideal gas which undergo quasi-static adiabatic expansion, obtain the expression $TV^{\gamma-1} = K$, where γ is the ratio of heat capacity at constant pressure to that at constant volume. (1+2+7)

   d) Two moles of an ideal gas at STP is expanded isothermally to thrice its volume. It is then made to undergoes isochoric change to attain its original pressure. Calculate the total work done in these processes. Take $R = 8.3\ \text{JK}^{-1}\text{mol}^{-1}$. (5)

PART B

3. a) Write Kelvin-Planck and Clausius statements of the second law of thermodynamics. Show that these two statements are equivalent. (5)

   b) Calculate the change in entropy when 20 g of ice at 0°C is converted into steam. [Given: latent heat of fusion of ice = 80 cal g^{-1}, latent heat of fusion of steam = 540 cal g^{-1}]. (5)

   c) Using Maxwell's relations, deduce first and second *TdS*-equations. Also, obtain the first *TdS*-equation in terms of volume expansivity (α) and isothermal compressibility (β_T). (6+4)

   d) State Stefan-Boltzmann's law of black body radiation. Plot spectral energy density of a black body with wavelength at different temperatures and discuss the results of these plots. (2+3)

4. a) Derive Boltzmann entropy relation $S = k_B \ln W$, where W is a thermodynamic probability. (5)

   b) Using the expression of thermodynamic probability of a Fermi-Dirac system, derive the expression for the distribution function and plot it as a function of energy at temperatures (i) T = 0 K and (ii) T > 0 K. (8+2)

   c) A box of volume 1cm^3 contains 4×10^{21} electrons. Calculate Fermi energy of these electrons. [Take: $m_e = 9.1\times10^{-28}\text{g}$ and $h = 6.62\times10^{-28}\text{erg s}$]. (5)

   d) Write the expression for N distinguishable particles partition function for an ideal gas and hence obtain expressions for heat capacity at constant (i) volume, and (ii) pressure. (5)

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