BPHE-106/PHE-06

ASSIGNMENT BOOKLET
Bachelor's Degree Programme (B.Sc.)

THERMODYNAMICS AND STATISTICAL MECHANICS

Valid from January 1, 2022 to December 31, 2022

It is compulsory to submit the Assignment before filling up the Term-End Examination Form.

Please Note

- **You can take electives (56 or 64 credits) from a minimum of TWO and a maximum of FOUR science disciplines, viz. Physics, Chemistry, Life Sciences and Mathematics.**
- **You can opt for elective courses worth a MINIMUM OF 8 CREDITS and a MAXIMUM OF 48 CREDITS from any of these four disciplines.**
- **At least 25% of the total credits that you register for in the elective courses from Life Sciences, Chemistry and Physics disciplines must be from the laboratory courses. For example, if you opt for a total of 64 credits of electives in these 3 disciplines, at least 16 credits out of those 64 credits should be from lab courses.**
- **You cannot appear in the Term-End Examination of any course without registering for the course. Otherwise, your result will not be declared and the responsibility will be yours.**

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2022

Dear Student

We hope you are familiar with the system of evaluation to be followed for the Bachelor's Degree Programme. At this stage you may probably like to re-read the section on assignments for Elective Courses in the Programme Guide that we sent you after your enrolment. A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, which consists of **one tutor-marked assignment (TMA)** for this 4-credit course. **Submit your assignment response at your Study Centre.**

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

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

ENROLMENT NO. : ………………………………………

NAME : ………………………………………

ADDRESS : ………………………………………

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COURSE CODE : ……………………………..

COURSE TITLE : ……………………….…….

ASSIGNMENT NO. : ………………………….…

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

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

2) Use only foolscap size good quality 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 and in your own words.
5) While solving problems, clearly indicate the question number along with the part being answered. Write units at each step of your calculations as done in your study material. Marks will be deducted for not adhering to this practice. Take care of significant digits in your work. Recheck your work before submitting it.
6) **This assignment will remain valid from January 1, 2022 to December 31, 2022**. However, you are advised to submit it within **12 weeks** of receiving this booklet to accomplish its purpose as a teaching-tool.

We strongly feel that you should retain a copy of your assignment response to avoid any unforeseen situation and append, if possible, a photocopy of this booklet with your response.

We wish you good luck.

Tutor Marked Assignment
THERMODYNAMICS AND STATISTICAL MECHANICS

Course Code: BPHE-106/PHE-06
Assignment Code: BPHE-106/PHE-06/TMA/2022
Max. Marks: 100

Note: Attempt all questions. Symbols have their usual meanings. The marks for each question are indicated against it.

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1. a) Calculate the temperature at which root mean square speed of nitrogen molecules exceeds their most probable speed by 200 ms^{-1}. (5)

   b) Using the expression for the number of molecules in a Maxwellian gas having speeds in the range v to $v + dv$

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

   Obtain an expression of most probable speed (v_ρ) of a molecule. (5)

   c) Define mean free path of the molecules of a gas. Show that it is equal to $\frac{1}{n\pi d^2}$ under zeroth order approximation. (5)

   d) Establish van der Waal's equation of state for n moles of a gas. (5)

   e) At 0°C temperature, the mean kinetic energy of molecules of hydrogen is 5.50×10^{-21} J and molar gas constant is $8.31\,\text{J mol}^{-1}\,\text{K}^{-1}$. Calculate Avogadro's number. (5)

2. a) A mass of an ideal gas ($\gamma = 1.5$) at 30°C is suddenly compressed to six times its original pressure. Calculate the final temperature of the gas. (5)

   b) What is an indicator diagram? Represent an (i) isobaric, (ii) isochoric, (iii) isothermal, and (iv) a cyclic process on an indicator diagram. (1+4)

   c) Show that for an ideal gas

$$\beta_T = \frac{1}{p} \quad \text{and} \quad \alpha = \frac{1}{T}$$

   where β_T is the isothermal compressibility and α is thermal expansivity.

   d) With the help of schematic diagram, describe the construction of platinum resistance thermometer. Write its any two principal merits. (4+1)

   e) Derive an expression for adiabatic lapse rate. (5)

3. a) Define entropy. Obtain an expression for change in entropy when two gases left in separate container are allowed to mix. (5)

   b) A freezer operates between – 13°C and 27°C. Calculate the maximum value of coefficient of performance (ω) for this refrigerator. With this ω, how much electrical energy would be required to freeze 0.5 kg of water, initially at 0°C. Given specific latent heat of fusion = $334\,\mathrm{kJ\,kg^{-1}}$. (5)

c) Write the expressions of four thermodynamic potentials. State one application of Gibbs free energy and an importance of Helmholtz-energy. (5)

d) Derive the Ehrenfest's equation for a second order phase transition. Plot temperature (T) versus heat capacity (Cp) for second order transition. (8+2)

4. a) The thermodynamic probability for a Fermi-Dirac system is given by

$$W = \prod \frac{g_i!}{(g_i - N_i)!N_i!}$$

Using this, derive an expression for the distribution function and plot it for T = 0K and T > 0K. (8+2)

b) Starting from the equation of motion of a linear harmonic oscillator, show that its phase space is an ellipse and also draw its phase space diagram. (4+1)

c) The expression for the partition function for an ideal gas made up of N-particles is given by

$$Z_N = V^N \left(\frac{2\pi m k_B T}{h^2}\right)^{3N/2}$$

Using this function, obtain expressions of (i) energy per molecule, and (ii) pressure. (5)

d) Show that the expression for Planck's law for energy density derived by Bose is given by

$$U_\nu d\nu = \frac{8\pi h}{c^3} \frac{\nu^3 d\nu}{\exp\left[\frac{h\nu}{k_B T} - 1\right]}$$ (5)

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