BPHE-106/PHE-06

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

THERMODYNAMICS AND STATISTICAL MECHANICS

Valid from January 1, 2020 to December 31, 2020

It is compulsory to submit the Assignment before filling in 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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THE PEOPLE'S UNIVERSITY

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2020

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, 2020 to December 31, 2020**. 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/2020
Max. Marks: 100

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

1. a) The expression for the number of molecules in a Maxwellian gas having speeds in the range v to $v + dv$ as

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

Using this relation, obtain an expression for average speed. Also, plot Maxwellian distribution function versus speed at three different temperatures. (5+1)

b) Calculate the temperature at which the oxygen molecules would have the same root mean square speed as of hydrogen molecules at room temperature (≈ 300 K). (4)

c) Obtain an expression for mean free path of the molecules in a gas in the first order approximation. Also, show that mean free path of the molecules in a gas decreases when all molecules are moving. (10)

d) Write van der Waal's equation of state for one mole of gas. Using this equation, obtain the reduced equation of state. (1+4)

2. a) For two states defined by $dV = 0$ and $dT \neq 0$, prove that the thermodynamic variables are connected through the relation:

$$\left(\frac{\partial V}{\partial P}\right)_T \left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial T}{\partial V}\right)_p = -1$$ (5)

b) For a platinum wire, the coefficients of variation of resistance with temperature are $\alpha = 3.94\times10^{-3}\,°C^{-1}$ and $\beta = -5.82\times10^{-7}\,°C^{-2}$. A thermometer is fabricated using this wire with $R_0 = 12.00\,\Omega$, where R_0 signifies the resistance of the material of wire at ice point. When the thermometer is placed in contact with a heat bath, the resistance is found to be $15.20\,\Omega$. Calculate the temperature of the bath. (5)

c) Show that the expression of the work done during an adiabatic process in terms of its initial and final temperature is

$$W = \frac{R}{\gamma - 1}\left[T_i - T_f\right]$$ (5)

d) i) Define adiabatic lapse rate and show that:

$$\frac{dT}{dh} = -\frac{\gamma - 1}{\gamma}\frac{Mg}{R}$$

Plot a graph between atmospheric temperature with altitude. (1+3+1)

ii) How many degrees of freedom does the gas molecules have if under standard conditions the gas density is 1.3 kg m^{-3} and the velocity of sound in it is $v = 330\ m\ s^{-1}$. (5)

3. a) Two separate containers filled with different gases. If these gases are allowed to mix, obtain an expression for entropy of mixing per mole of the mixture. Does the entropy decreases in the process of mixing of two gases? (5)

b) Using Maxwell's relations, deduce first, second and third TdS-equations. (10)

c) For second order phase transitions, show that

$$\frac{\Delta p}{\Delta T} = \frac{C_{p_2} - C_{p_1}}{Tv(\alpha_{p_2} - \alpha_{p_1})}$$

Plot temperature variation of heat capacity for second order phase transition. How does this plot is different from the plot of lambda transitions? (6+2+2)

4. a) For a Bose-Einstein system, the expression for the thermodynamic probability is :

$$W = \prod \frac{(g_i + N_i - 1)!}{N_i!(g_i - 1)!}$$

Derive an expression for the Bose-Einstein distribution function. (10)

b) A box of volume 1 cm^3 contains 5.2×10^{21} electrons. Calculate their Fermi momentum and Fermi energy.

Take:

$$m_e = 9.1 \times 10^{-28} \text{g}, \; m_n = 1.67 \times 10^{-24} \text{g} \; \text{and} \; h = 6.62 \times 10^{-27} \text{ergs}$$ (5)

c) The expression for partition function for an ideal gas consisting of N indistinguishable particles is given as

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

Using this relation, obtain an expression for Sackur-Tetrode equation. Also, obtain the expression of Helmholtz free energy in terms of deBroglie wavelength. (7+3)

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