BINDURA UNIVERISTY OF SCIENCE EDUCATION

FACULTY OF SCIENCE EDUCATION/ SCIENCE AND ENGINEERING

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION/ DEPARTMENT OF ENGINEERING AND PHYSICS

BACHELOR OF SCIENCE EDUCATION DEGREE PHYSICS / BACHELOR OF SCIENCE HONOURS DEGREE IN ENVIRONMENTAL PHYSICS AND ENERGY SOURCES

PH301/HPH216: THERMODYNAMICS

JUN 2025

DURATION: 3 HOURS

INSTRUCTIONS

Answer ALL parts of Section A and any THREE questions from Section B.

Section A carries 40 marks and each question in Section B carries 20 marks.

CONSTANTS: Planck's constant $h = 6.626 \times 10^{-34}\ \mathrm{m^2kg/s}$

Boltzmann constant, $k = 1.38 \times 10^{-23}$ J/K,

Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

The molar mass constant, R = 8.31 J K^{-1} mol^{-1}

SECTION A

Question 1.

(a) What is meant by the following?

- i) Thermodynamic system
- ii) Adiabatic walls
- iii) Isolating wall
- iv) Metastable equilibrium
- v) Thermal contact (5)

(b) State the properties of a thermodynamic universe? (4)

(c) Explain why the law of increasing entropy is often described as providing the " arrow of time". (3)

(d) For an irreversible free expansion, show that $dS = nRln2$

n= number of moles and R=universal gas constant (4)

(e) Distinguish between

(i) Intensive and extensive properties of a Thermodynamic system

(ii) Superconductivity and Superfluidity. (4)

(f) Derive the expression for the entropy of one mole of an ideal gas. (5)

(g) State Clausius' statement and Kelvin-Plank the second Laws of Thermodynamics. (2)

(h) (i) State the Carnot-Clausius theorem for a perfect gas. (2)

(ii) For an infinitesimal reversible process, show that C_P=C_V+nR (5)

(i) Outline the main

(i) Properties of first order and second order phase changes.

(ii) Causes of entropy change (6)

SECTION B

Question 2

a) State the general equation of thermodynamics. (1)

b) (i) Define the Helmholtz function (F). (1)

(ii) Show that for an infinitesimal change in the state variables, the Helmholtz free energy function is $dF = -pdV - SdT$ (6)

(iii) State the Internal energy function (U), Enthalpy (H) state function and the Gibbs free energy state function(G) . (3)

c) Using the U, H and G state functions, derive the third and the fourth Maxwell relations (9)

Question 3

a) What is an isentropic process? .Give one example. (3)

b) (i) A beaker of water with thermal capacity, $C_{P,}$is heated

from $T_i = 293K$ to $T_f = 373K$

The heating process is done reversibly and isobaric ally between the two temperatures. Calculate the net entropy change of the Universe ($\Delta S^{universe}$)

that occurs. (6)

(ii) What is $\Delta S^{universe}$ if the water is heated in two stages by placing it

first on a reservoir at 50°C and when it reaches that temperature, transferring it to a second reservoir at 100 °C for the final heating? (4)

c) Calculate the change in entropy of 5kg of water when it is heated

reversibly from 0°C to 100°C (specific heat capacity of water

at 100°C $is\ 4.0x10^3 Jkg^{-1}$°C^{-1} (7)

Question 4

(a) (i)State the third law of thermodynamics. (1)

(ii) Show that for a gas expanding isothermally from V_1 to V_2

$$W = P_2V_2\ln(\frac{V_2}{V_1})$$ (6)

(b) (i) What is a photon? (1)

(ii) State Rayleigh-Jeans' formula for the intensity of

blackbody radiation and explain the symbols that you

have used. (4)

(iii) Describe and explain the ultraviolet catastrophe phenomena (4)

(c) Show that for real gases (Van der Waals) the equation of state is given as

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$ (4)

Question 5

a) State the equations of state for ideal and real gases. (4)

b) (i) Using the central equation of thermodynamics

$$Tds = dU + pdV \qquad \text{Show that}$$

$$dS = C_V \frac{dT}{T} + \alpha_v \beta_T dV \qquad (6)$$

(ii) Given that $C_p = \left(\frac{\partial H}{\partial T}\right)_p$. Show that $C_P - C_V = \alpha_V^2 \beta_T VT$ (5)

c) Show that the Clausius -Clapeyron equation for the slope of the phase boundary is given as

$$\frac{dP}{dT} = \frac{l}{T(V_2 - V_1)} = \frac{L}{T(V_2 - V_1)} \qquad (5)$$

Question 6

(a) Explain the concepts "Degradation of energy" and "Energy crisis" in relation to thermodynamics (6)

(b) Outline the main properties of first order and second order phase changes. Give two examples of each of them. (6)

(c) (i)For an ideal gas where $U = U(T)$ and $C_v = \left(\frac{\partial U}{\partial T}\right)_v = \frac{dU}{dT}$,

Show that the entropy of one mole of an ideal gas is given by the expression

$$S = C_V lnT + RlnV + S_O \qquad \text{Where } S_o \text{ is a constant}$$

V is the volume of one mole of the gas and T is temperature? (4)

(ii) Express the entropy (S) as a function of temperature and pressure. (4)

END OF EXAM