NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED PHYSICS

THERMAL PHYSICS II

SPH 2104

First Semester Examination Paper

December 2024

This examination paper consists of 4 pages

Time Allowed:	3 hours
Total Marks:	100
Special Requirements:	None
Examiner's Names:	Mr B Sibanda

INSTRUCTIONS

ANSWER <u>ALL</u> PARTS OF QUESTION 1 IN SECTION A AND ANY <u>THREE</u> QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

MARK ALLOCATION

QUESTION	MARKS
1.	40
2.	20
3.	20
4.	20
5.	20
6.	20
Maximum possible mark	**100**

1. (a) Starting from the fundamental equation of thermodynamics, find an expression

for the Entropy as a function of pressure and Temperature. [6]

(b) Write down the total differential of the Helmholtz potential function

involving its characteristics variables. Define all symbols. [4]

(c) (i) Derive the equation $\left(\frac{\partial C_V}{\partial V}\right)_T = T\left(\frac{\partial^2 P}{\partial T^2}\right)_V$. [5]

(i) Prove that C_V of an ideal gas is a function of T only. [2]

(d) (i) Derive the equation $\left(\frac{\partial C_P}{\partial P}\right)_T = T\left(\frac{\partial^2 V}{\partial T^2}\right)_P$. [5]

(i) Prove that C_P of an ideal gas is a function of T only. [2]

(e) Show that in a Joule-Thompson expansion, no temperature change occurs if

$\left(\frac{\partial V}{\partial T}\right)_P = \frac{v}{T}$. [4]

(f) Derive the expression for the efficiency of a Carnot cycle directly from a TS
diagram. [4]

(g) Prove that the slope on a TS diagram of:

(i) An isochoric curve is $\frac{T}{C_V}$. [4]

(ii) An isobaric curve is $\frac{T}{C_P}$. [4]

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2.   (a)   If β_p is the expansivity of a substance, show that for any substance

$$C_p - C_v = \frac{VT\beta_p^2}{\kappa_T}$$ [6]

(b) (i)   Explain the behaviour of an ideal gas as the absolute temperature approaches zero.

   (ii) Show from the expression in (a) that $C_p = C_v$ as the temperature approaches zero.   [10]

(c)   Show that the absolute zero temperature is not attainable.   [4]

3.(a)   Derive the third TdS equation: $TdS = C_v\left(\frac{\partial T}{\partial p}\right)_v dp + C_p\left(\frac{\partial T}{\partial V}\right)_p dV.$ [5]

   (b)   Show that the three TdS equations may be written as follows.

       (i) $TdS = C_v dT + \frac{\beta T}{\kappa_T} dV$ [5]

       (ii) $TdS = C_p dT - \beta VT dp$ [5]

       (iii) $TdS = \frac{C_v \kappa}{\beta} dp + \frac{C_p}{\beta_p} dV$ [5]

4.   (a)   Show that the Joule-Kelvin coefficient $\mu = \frac{T\left(\frac{\partial V}{\partial T}\right)_p}{C_V} - \frac{V}{C_V}$ [6]

   (b)   Find the expression for the inversion temperature of a van der Waals gas.   [6]

   (c)   Derive and name an equation which applies to phase transitions of the

   first kind.   [8]

5.   (a)   Derive the equation $\left(\frac{\partial C_p}{\partial p}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_p$ [6]

   (b)   The free energy F of a gas is:

$$F = AT\ln(V - B) - \frac{C}{V} + DT^2 + E$$

   where   A, B, C, D and E are constants.

       (i)   Derive an expression for the pressure P   [4]

       (ii)   Give an expression for C_V [4]

   (c)   (i) Distinguish between transitions of the first kind and those of second kind   [4]

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(ii) In a phase Transition of the first kind which potential function remains the same. [2]

6. (a) State Nernst's Theorem. [4]

(b) Using Nernst Theorem:

(i) Find the expression for the Entropy of an ideal gas. [5]

(ii) If the expression $S(V, T)$ in (i) above does not satisfy Nernst's Heat Theorem, explain why. [6]

(iii) Show that the absolute zero temperature is unattainable [5]

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