UNIVERSITY OF RUHUNA
BACHELOR OF SCIENCE GENERAL DEGREE LEVEL II (SEMESTER I)
EXAMINATION – July/August 2023

Subject: PHYSICS
Course Unit: PHY2114

Part II

Answer FIVE (05) questions only. **Time: 02 Hours & 30 Minutes**

(All symbols have their usual meaning)
$R = 8.314\ J\ mol^{-1}K^{-1}$

$1\ atm = 1.0 \times 10^5\ Nm^{-2}$

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01. a) Write down the first law of thermodynamics describing each term. **(03 marks)**

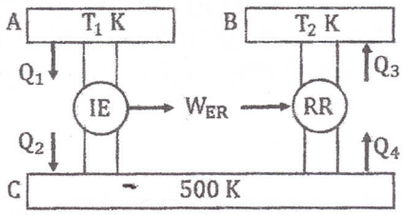
b) One mole of an ideal gas ($\gamma = 5/3$) at (P_1, V_1, T_1) is capable of executing following processes.

$A \rightarrow B$: the gas expands isothermally until its volume becomes $8V_1$.
$B \rightarrow C$: the gas compresses through an isobaric process until its volume becomes $2V_1$.
$C \rightarrow D$: the gas undergoes an isochoric process until its pressure becomes $2^{-5/3}P_1$.
$D \rightarrow A$: the gas comes back to the initial state through an adiabatic process.

(i) Draw the PV diagram for the above cyclic process. **(04 marks)**
(ii) Calculate the pressure at state B in terms of P_1. **(02 marks)**
(iii) If $P_1 = 1.5\ atm$ and $V_1 = 2 \times 10^{-2}\ m^3$, calculate T_1. **(03 marks)**
(iv) Show that the work done by the gas during the cyclic process is given by $W = RT_1\left(ln8 - \frac{9}{4} + 3 \times 2^{-5/3}\right)$. If $2^{-5/3} = 0.315$, calculate W. **(11 marks)**
(v) Using the result in part (iv), estimate the total internal energy increased and total heat absorbed by the system. **(02 marks)**
[**Hint:** When an ideal gas changes its state from state $A(P_1, V_1, T_1)$ to state $B(P_2, V_2, T_2)$ isothermally and adiabatically, the work done by the gas is given by $W_{AB} = nRT\ \ln\left(\frac{V_2}{V_1}\right)$ and $W_{AB} = \frac{1}{1-\gamma}[P_2V_2 - P_1V_1]$, respectively. Here, $\gamma = (C_P/C_V)$].

02. a) Define the efficiency (η) of an engine and the coefficient of performance (K) of a refrigerator. **(04 marks)**

b) Figure shows a reversible engine (IE) and an irreversible engine (RR) operating among three reservoirs A, B and C.



(i) If the value K of the Carnot refrigerator is 2, calculate the temperature T_2. **(03 marks)**

(ii) If the maximum possible efficiency of a hypothetical engine operating between reservoirs A and B is 50%, calculate T_1. **(05 marks)**

(iii) If the temperatures of the reservoirs B and C are increased by 10 K, explain whether the efficiency of the reversible engine would be increased, decreased or otherwise remained the same. **(05 marks)**

(iv) If $W_{ER} = 300J$, calculate Q_3 and Q_4. **(04 marks)**

(v) If the efficiency of the irreversible engine is half times the efficiency of a hypothetical reversible engine operating between the reservoirs A and C, calculate Q_1 and Q_2. **(04 marks)**

03. a) Write down the Maxwell's equations in thermodynamics. **(04 marks)**

b) Using those equations derive the first and second TdS equations. **(10 marks)**

c) (i) Using the first law of thermodynamics and the first TdS equation, obtain the internal energy equation $\left[\frac{\partial U}{\partial V}\right]_T = T\left[\frac{\partial P}{\partial T}\right]_V - P$ **(07 marks)**

(ii) Using above results, show that $\left[\frac{\partial U}{\partial V}\right]_T = 0$ for a perfect gas. **(04 marks)**

04. a) Write down the Clausius Clapeyron's equation for liquid-vapor equilibrium in mathematical form defining all terms. **(05 marks)**

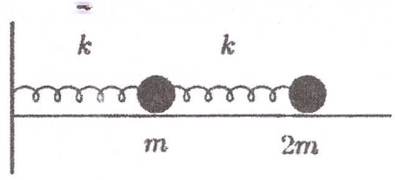
b) Show that the Clausius Clapeyron's equation can also be expressed as

$$\frac{dP}{dT} = \frac{\rho_1\rho_2 L}{T(\rho_1 - \rho_2)} \quad \text{and} \quad \frac{dP}{dT} = \frac{|s_2 - s_1|}{(V_2 - V_1)}$$ **(06 marks)**

c) Using the Clausius Clapeyron's equation, discuss the behavior of boiling points and melting points of materials with pressure. **(08 marks)**

d) The atmospheric pressure at the top of mountain Hanthana is 0.95 atm. The density of steam and water are 0.595 kgm^{-3} and 10^3 kgm^{-3}, respectively. If the latent heat of vaporization of water is 2.27×10^6 Jkg^{-1}, calculate the total energy required to evaporate 10 g of water at 10 °C at the top of mountain Hanthana. Specific heat capacity of water = 4190 $Jkg^{-1}K^{-1}$. **(06 marks)**

05. A system of two identical massless springs of spring constant k and two particles of masses m and $2m$ are attached to a wall as shown in the Figure below. The system has a one dimensional (1-D) motion on a frictionless horizontal plane.



a) What are the generalized coordinates of the system? **(04 marks)**

b) Write down the Lagrangian function (L) of the system. **(06 marks)**

c) Determine the equations of motion for the system using the Lagrange's method. **(08 marks)**

d) If the motion of the particle of mass m is suddenly stopped, find the period of oscillations for the motion of the particle of mass $2m$. **(07 marks)**

06. An object of mass m moves under the influence of a central force given by $F(r) = -2\alpha r$, where α is a constant.

a) Determine the potential due to the above central force. **(04 marks)**

b) Show that the angular momentum (l) of the object is conserved. **(06 marks)**

c) Show that the equation of motion for r, the displacement of the object from the reference point, is given by

$$m\ddot{r} = \frac{l^2}{mr^3} - 2\alpha r \,.$$ **(06 marks)**

d) For a circular orbit of the object, find the radius of the orbit (r_0) of the object. **(05 marks)**

e) Sketch the curve of effective potential vs r. **(04 marks)**

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