UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE LEVEL II (SEMESTER I)

EXAMINATION – January/February 2022

Subject: PHYSICS

Course Unit: PHY2114 **Time: 03 Hours**

Part II

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

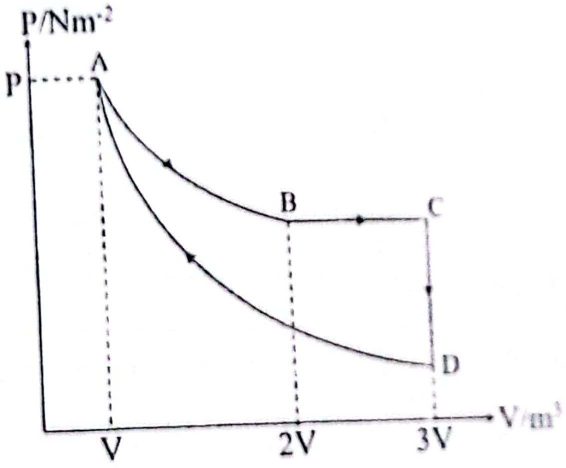
(All symbols have their usual meaning)

$R = 8.314\ J\,mol^{-1}K^{-1}$

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

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

b) One mole of an ideal gas ($\gamma = 3/2$) is capable of executing a cyclic process as indicated in the P-V diagram shown below.



(i) If the above cyclic process consists of adiabatic, isothermal, isobaric and isochoric processes, identify each process. **(04 marks)**

(ii) If the temperature at the state A is T K, calculate pressure and temperature at states B and C in terms of P, and T. Show that the pressure and the temperature at state D is given by $\frac{P}{3^{\gamma}}$ and $\frac{T}{3^{\gamma-1}}$ respectively. **(04 marks)**

(iii) Show that the work done by the gas during the cyclic process is given by

$$W = RTln2 + \frac{PV}{2} + \frac{PV}{1-\gamma}(1 - 3^{1-\gamma})$$

[**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, $\gamma = (C_P/C_V)$]

(07 marks)

(iv) Using the result in part (iii) to show that
$W = RT\left(ln2 - \frac{3}{2} + \frac{2}{\sqrt{3}}\right)$. **(03 marks)**

(v) If T = 300 K, find the work done by the gas during the cyclic process. **(02 marks)**

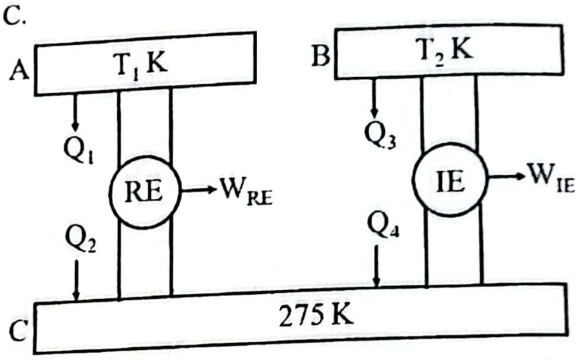
(vi) If T = 300 K, calculate the heat absorbed by the system during the isothermal process.
(02 marks)

02. a) Briefly explain the physical meaning of the second law of thermodynamics. **(02 marks)**

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

c) Indicate a Carnot cycle in a T-S diagram. Using the T-S diagram, obtain an expression for the efficiency of the Carnot cycle. **(05 marks)**

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



(i) If the efficiencies of both engines are identical compare the temperatures of the reservoirs A and B. **(02 marks**

(ii) If the temperatures of the reservoirs A and C are increased by 10 K, explain whether the efficiency of the reversible engine would be increased, decreased or otherwise remained the same. **(03 mark**

(iii) If the efficiency of the reversible engine is 45%, calculate T_1. **(02 mark**

(iv) If the coefficient of performance of a hypothetical reversible refrigerator operating between the reservoirs A and B to cool the reservoir A is 2.5, calculate T_2.
(03 mark

(v) If W_{RE} = 450 and W_{IE} = 495 J, calculate Q_1, Q_2, Q_3 and Q_4. **(04 mark**

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) A mass of liquid Ether at 20 ^{0}C is adiabatically compressed by increasing the pressure on it by 10^6 Nm^{-2}. Using the TdS equations, calculate the rise in temperature of the Ether.

[The density of Ether at 20 ^{0}C is 0.71×10^3 kgm^{-3}, specific heat of Ether at constant pressure is 2.352×10^3 Jkg^{-1}K^{-1} and the volume expansion coefficient of Ether is 0.00163 K^{-1}]

(11 marks)

04. a) Derive the Clausius Clapeyron's equation. (10 marks)

b) Using the Clausius Clapeyron's equation, discuss the behaviour of melting points and boiling points of materials with pressure. (07 marks)

c) Calculate the total energy required to completely evaporate 1 kg of water at 25 °C at Hantana. Assume that the pressure at Hantana is 0.95 atm.

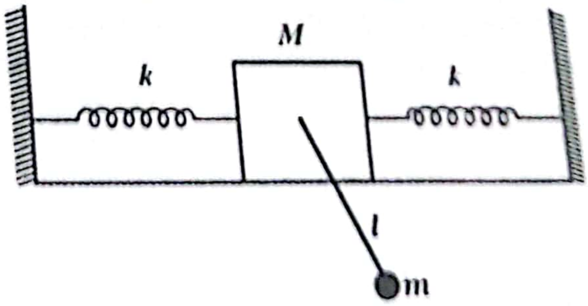
Specific volume of steam = 1.68 m^{3}kg^{-1}

Latent heat of vaporization of water = 2.27×10^6 Jkg^{-1}

Specific heat of water = 4200 Jkg^{-1}K^{-1}

(08 marks)

05. A cart of mass M is attached to two identical springs of spring constant k and the other ends of the springs are attached to walls as shown in the figure. This cart is free to slide along a horizontal frictionless rail. A pendulum of length l and mass m hangs from the cart.



a) What is/are the generalized coordinate(s) of the system? (04 marks)

b) Write down the Lagrangian for the system. (06 marks)

c) Determine the equation(s) of motion for the system. **(08 marks)**

d) If the springs are removed from the system and the cart is free to move along the rail itself find the period of oscillations of the pendulum assuming it undergoes small oscillations. **(07 marks)**

06. a) Consider a particle of mass m subject to a central force only described by the potential $V(r)$

(i) Derive the equations of motion for the particle. **(06 marks)**

(ii) Show that the angular momentum (l) of the particle is a constant of motion. **(02 marks)**

(iii) Show that the total energy of the particle is given by $E = \frac{1}{2}m\dot{r}^2 + V_{eff}$.

where, $V_{eff} = \frac{l^2}{2mr^2} + V(r)$. **(03 marks)**

(iv) Derive the equation $\left(\frac{1}{r^2}\frac{dr}{d\theta}\right)^2 = \frac{2mE}{l^2} - \frac{1}{r^2} - \frac{2mV(r)}{l^2}$. **(05 marks)**

b) Consider the particle mentioned in part (a) is subject to a potential $V(r) = \beta r^2$.

(i) Show that the equation in part (a) (iv) is reduced to

$$\left(\frac{1}{2}\frac{dy}{d\theta}\right)^2 = \frac{2mEy}{l^2} - y^2 - \frac{2m\beta}{l^2}$$ with the change of variables $y = \frac{1}{r^2}$. **(04 marks)**

(ii) Using the definition $z = y - \frac{mE}{l^2}$, show that $z = B\,Cos[2(\theta - \theta_0)]$ is the solution

where, $B = \left(\frac{mE}{l^2}\right)^2\left(1 - \frac{2\beta l^2}{mE^2}\right)$.

(**Hint:** $\int \frac{1}{\sqrt{A^2-z^2}}dz = Cos^{-1}(\frac{z}{A}) + constant$) **(05 marks)**

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