UNIVERSITY OF RUHUNA

B.Sc. General Degree Level II (Semester I) Examination – August/September 2017

Subject: PHYSICS

Course Unit: PHY 2114 **Time: 02 hours & 30 minutes**

Part II

Answer FIVE (05) Questions only.

(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) Show that two reversible adiabatics of a given system never intersect each other. (04 marks)

c) Show that the slope of adiabatic is greater than the slope of isotherm for a given system. (04 marks)

d) One mole of an ideal gas (γ=5/3) at state (P_1, V_1, T_1) is capable of executing following processes.

A→B: the gas undergoes an isobaric expansion until its volume becomes $3V_1$.

B→C: the gas undergoes an isothermal compression until the pressure becomes $2P_1$.

C→D: the gas undergoes an isochoric process.

D→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) Find pressure and volume in each step in terms of P_1 and V_1. (04 marks)

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

$$W = P_1V_1\left(2 - ln2 - \frac{3}{2}\left(1 - \left(\frac{3}{2}\right)^{2/3}\right)\right).$$ (06 marks)

02. a) What is meant by a reversible engine and an irreversible engine? (03 marks)

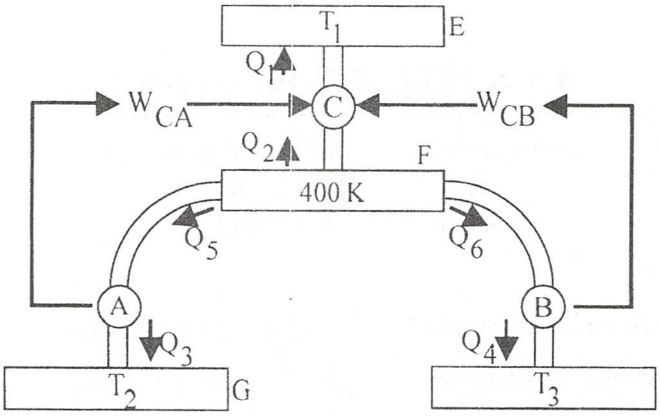
b) Define the efficiency (η) of a heat engine and the coefficient of performance (K) of a refrigerator.

(04 marks)

c) Show that the coefficient of performance of a Carnot refrigerator can be written as

$K = \frac{T_C}{T_H - T_C}$. (03 marks)

d) Figure shows a Carnot refrigerator and two Carnot engines operating among four reservoirs (*E, F, G* and *H*).



(i) If a heat engine cannot be operated between the reservoirs G and H, show that the efficiencies of two engines are identical. (03 marks)

(ii) If the temperatures of the reservoirs E and F are decreased by 5 K, explain whether the coefficient of performance of the refrigerator would be increased, decreased or otherwise remained constant? (04 marks)

(iii) If $\eta_A = \eta_B = 50\%$, $K_C = 1/2$, Q_1=400J and W_{CA}= 100J, calculate T_1, T_2, T_3, Q_2, Q_3, Q_4, Q_5, and Q_6. (08 marks)

03. a) Derive the first Tds equation. (06 marks)

b) Using the Tds equations, obtain the heat capacity equation,

$$C_p - C_V = -T\left(\frac{\partial V}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial V}\right)_T.$$ (11 marks)

c) Show that $C_p \geq C_v$, always. (03 marks)

d) Show that $C_p - C_v = nR$ for a perfect gas, using the result you obtained in part (b). (05 marks)

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

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

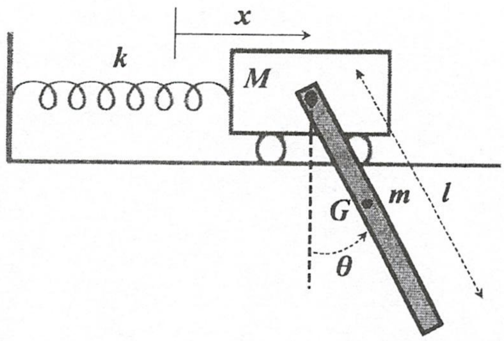
$$\frac{dP}{dT} = \frac{\rho_1 \rho_2 L}{T(\rho_1 - \rho_2)} \quad \text{and} \quad \frac{dP}{dT} = \frac{|s_2 - s_1|}{(V_2 - V_1)}.$$ (05 marks)

c) The density of water at 100 °C and 1 atm is 958.8 kgm^{-3} and the density of steam at the same condition is 0.597 kgm^{-3}.

(i) If the latent heat of vaporization of water is 2257 $kJkg^{-1}$, calculate the slope of the vaporization curve of water at 1 atm and 100 °C. (04 marks)

(ii) If the atmospheric pressure at the top of the mountain Everest is 0.35 atm, find the boiling point of water at the top of the mountain. (06 marks)

05. A *cart and pendulum*, shown in the figure, consists of a cart of mass, M, moving on a frictionless horizontal surface, acted upon by a spring with spring constant k. A pendulum, a uniform rod of length, l, and mass, m, is suspended at the center of mass of the cart.

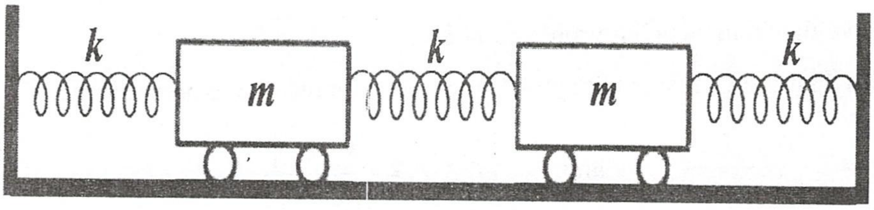


a) What are the generalized coordinates of the system? (04 marks)

b) Write down the Lagrangian for the system. (09 marks)

c) Determine the equations of motion for the system. (12 marks)

06. Consider a system of two identical carts attached to three identical springs as shown in the following figure. The ends of the left and the right springs are fixed to walls and the two carts of same mass are free to move on a frictionless horizontal plane. Assume only small displacements from equilibrium.



a) Find the normal frequencies of vibrations of the system for small displacements. (15 marks)

b) Determine the normal modes of vibrations of the system for small displacements. (10 marks)

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