UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE LEVEL II (SEMESTER I) EXAMINATION – NOVEMBER/DECEMBER 2019

Subject: PHYSICS

Course Unit: PHY 2114

Part II

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

(All symbols have their usual meaning)

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

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

Stefan's constant $(\sigma) = 5.7 \times 10^{-8}$ $\text{Js}^{-1}\text{m}^{-2}\text{K}^{-4}$

1) Write down the first law of thermodynamics in mathematical form, describing each term. Which conservation law reflects under the first law? **(04 marks)**

b) Show that the slope of an adiabatic curve is γ times slope of an isothermal curve. Here, $\gamma = \frac{C_P}{C_V}$. **(04 marks)**

c) One mole of an ideal gas $\left(\gamma = \frac{5}{3}\right)$ at (P_1, V_1, T_1) is capable of executing following processes.

A→B: the gas expands isobarically until its volume becomes $2V_1$.

B→C: the gas expands adiabatically until its volume becomes $8V_1$.

C→D: the gas undergoes an isothermal process.

D→A: the gas returns to the initial state through an isochoric process.

[When n moles of an ideal gas at temperature T K changes its state from (P_1, V_1, T_1) to (P_2, V_2, T_2), the work done by the gas (W) during isothermal and adiabatic processes are given by $W = nRT_1 \ln\left(\frac{V_2}{V_1}\right)$ and $W = \frac{(P_2V_2 - P_1V_1)}{1-\gamma}$, respectively.]

(i) Draw a PV diagram for the above cyclic process. **(03 marks)**

(ii) Find pressure at the status C and D in terms of P_1. **(03 marks)**

(iii) If the temperature during the isothermal process is T_2, show that the work done by the gas (W) during the cyclic process is given by;

$$W = 2.8\, P_1V_1 + RT_2 \ln\left(\frac{1}{8}\right).$$

(05 marks)

(iv) If $P_1 = 1.5\ atm$ and $V_1 = 0.02\ m^3$, calculate T_1 and T_2. Hence, calculate W. **(04 marks)**

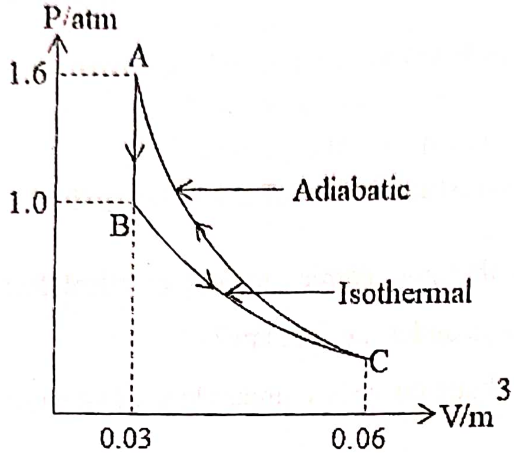
(v) Calculate the internal energy change during the process C→D. **(02 marks)**

02. a) Indicate a Carnot cycle in a T-S diagram. **(03 marks)**

b) Show that the total change of entropy of a Carnot cycle is zero. **(04 marks)**

c) State the Clausius theorem. Hence, show that the entropy is a state function. **(06 marks)**

d) One mole of an ideal gas ($C_V = \frac{3R}{2}$) is capable of executing the reversible cyclic process as indicated in the diagram shown below.



(i) Calculate the temperatures of the system at states A, B and C. **(06 marks)**

(ii) Entropy change of an ideal gas (for 1 mol) between two states is given by

$$S_2 - S_1 = C_V \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right).$$

Using this result, calculate the entropy change of the isochoric process. **(03 marks)**

(iii) If the heat exchanged during the isothermal process is 2079.2 J, calculate the total entropy change of the cyclic process. **(03 marks)**

03. a) Derive first *TdS* equation. **(08 marks)**

b) Write down second *TdS* equation. **(02 marks)**

c) Using the *TdS* equations, obtain the heat capacity equation,

$$C_p - C_V = -T\left(\frac{\partial V}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial V}\right)_T.$$ **(08 marks)**

d) Define the volume expansion coefficient (β), isothermal compressibility (K_T) and isothermal bulk modulus (k_T). **(03 marks)**

e) Show that $C_p - C_v = TV\beta^2 k_T = \frac{TV\beta^2}{K_T}$. **(04 marks)**

a) Inner and outer radii of a cylindrical shell of length ℓ are a and b respectively. The temperatures of the inner and outer surfaces of the shell are maintained at θ_1 and θ_2 ($\theta_1 > \theta_2$) respectively. The thermal conductivity of the material of the shell is K.

(i) Show that the radial rate of heat transfer through the cylindrical shell is given by

$$\dot{Q} = \frac{2\pi K\ell(\theta_1-\theta_2)}{\ln\left(\frac{b}{a}\right)}.$$ **(07 marks)**

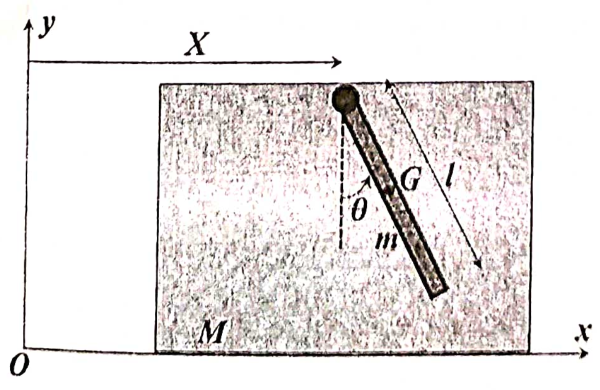
(ii) Obtain an expression for the temperature at a distance r ($a < r < b$) from the axis of the cylindrical shell. **(06 marks)**

(iii) If $a = 3$ cm, $b = 10$ cm, $\theta_1 = 150\ ^0$C, $\theta_2 = 0\ ^0$C and $\ell = 1$ m, calculate the temperature at $r = 5$ cm. **(02 marks)**

b) (i) State the Stefan's law of radiation. How would you apply this law to a black body and a normal body? Explain briefly. **(05 marks)**

(ii) A blackened Copper sphere is placed in a surrounding of temperature 27 ^{0}C. The diameter and the temperature of the outer surface of the sphere are 2 cm and 127 ^{0}C respectively. Calculate the rate of energy loss due to radiation from the Copper sphere. Assume that the blackened Copper sphere acts as a black body. **(05 marks)**

A box of mass M is sliding on a frictionless horizontal surface. The horizontal distance to the center of mass of the box from the origin is denoted by X. A uniform rod of mass m and length l is suspended at the center of the top of the box. Assume that the motion of the rod and the box is constraint to the x-y plane.



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

b) Write down the Lagrangian of the system. (11 marks)

c) Determine the equations of motion for the system. (10 marks)

06. An object of mass m moves under the influence of a central force $\frac{-k}{r^2}$.

a) What is the central potential of the object? (05 marks)

b) Show that the angular momentum (l) of the object is conserved. (08 marks)

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

$$m\ddot{r} = \frac{l^2}{mr^3} - \frac{k}{r^2}.$$

(06 marks)

d) Show that the period for a circular orbit of radius r_0 of the object is given by

$$T = 2\pi\sqrt{\frac{mr_0^3}{k}}.$$

(06 marks)

@@@@@@@@@@@@@@@@@@@@@@@@@@