UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE LEVEL II(SEMESTER I) EXAMINATION JULY 2016

Subject:PHYSICS
Course Unit: PHY2114

Time: Two hours & 30 minutes

Part II

Answer FIVE(05) questions only
At least 01(ONE) question from **Part B** should be answered

All symbols have their usual meaning

Part A

1. (a) Explain the following statements briefly.

   i. Radiators are used to cool almost all petrol and diesel engines in vehicles except one type.

   (04 marks)

   ii. When touched a piece of metal and a piece of wood which are at same temperature ($<$ body temperature) one can feel that the metal piece is colder than the wooden piece.

   (03 marks)

   (b) One end of a metal rod of uniform cross section and length 10 m is in contact with ice at 0 ℃ and the other end with water at 100 ℃. The whole system is insulated from the surroundings. At what point along the rod should the temperature of 175 ℃ be maintained, so that at the steady state, the mass of ice melted is equal to the mass of steam produced in a given interval of time. Latent heat of vaporization of water and latent heat of fusion of ice are $2.27 \times 10^6\,\mathrm{J\,kg^{-1}}$ and $3.36 \times 10^5\,\mathrm{J\,kg^{-1}}$, respectively.

   (10 marks)

   (c) If the surface temperature of the sun is 6000 K, calculate the sun's thermal radiation energy falling on the earth per second per square meter.

   Distance from sun to earth $R = 1.5 \times 10^{11}\,\mathrm{m}$

   Radius of the sun $r_s = 6.9 \times 10^8\,\mathrm{m}$

   Stefan's-Boltzmann constant, $\sigma = 5.7 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

   Assume that the emissivity of the sun $e = 1$ (08 marks)

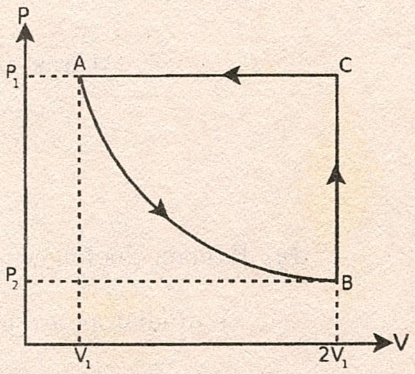
2. (a) Write down the first law of thermodynamics. Define each term and briefly explain the physical meaning of the law.

(05 marks)

(b) What is meant by thermally contacted and physically contacted systems? Explain briefly.

(02 marks)

(c) One mole of an ideal gas can perform the cyclic process indicated in the PV diagram.



i. If the process $A \longrightarrow B$ is an isothermal process identify heat absorbing and heat rejecting processes.

(03 marks)

ii. Find temperatures at the points A, B and C in terms of P_1, V_1 and R.

(03 marks)

iii. If $C_P = \frac{5R}{2}$ and $C_V = \frac{3R}{2}$, calculate the amounts of heat absorbed/rejected by the gas during the processes $B \longrightarrow C$ and $C \longrightarrow A$.

(04 marks)

iv. Calculate the work done by the gas during the cyclic process.

(05 marks)

v. If the heat absorbed by the gas during the process $A \longrightarrow B$ is Q, obtain an expression for Q.

(03 marks)

3. (a) Write down the second law of thermodynamics. Explain the physical meaning of this law.

(03 marks)

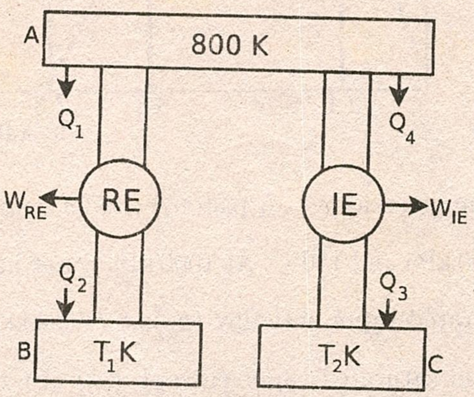
(b) Compare the differences between a reversible engine and an irreversible engine.

(03 marks)

(c) Consider a four stroke engine. Name four strokes and write down which stroke generates the highest amount of heat.

(05 marks)

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



i. If the efficiencies $\eta_{RE} = \eta_{IE} = 40\%$ **compare** the temperatures of the reservoirs B and C.

(03 marks)

ii. Calculate the temperature T_1.

(03 marks)

iii. If the coefficient of performance of a hypothetical Carnot refrigerator operating between the reservoirs B and C is 1.0, calculate T_2.

(04 marks)

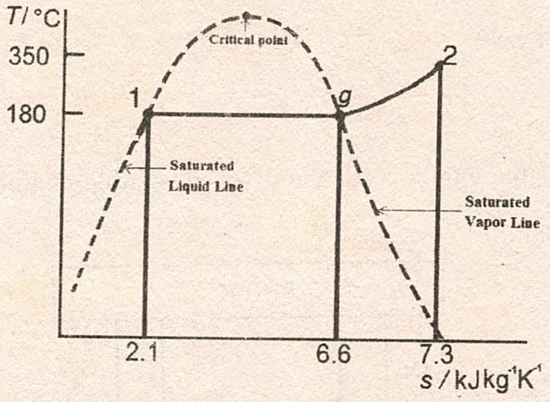
iv. If $W_{RE} = W_{IE} = 300\,\text{J}$, calculate Q_1, Q_2, Q_3 and Q_4.

(04 marks)

4. (a) Define the quantity Enthalpy (H) in a thermodynamic process. Show that the heat transfer in to a control-mass, Q_{in} during an isobaric process, can be written as $Q_{in} = H_2 - H_1$.

(05 marks)

(b)



Consider the T-s diagram given above. A piston/cylinder combination has 2 kg of water as a saturated-liquid at 1000 kPa and 180°C. At 1000 kPa water has a saturated-liquid enthalpy (h_f) of 763 kJ kg^{-1}, saturated-vapor enthalpy (h_g) of 2778 kJ kg^{-1}, saturated-liquid entropy s_f of 2.1 kJ kg^{-1} K^{-1}, and saturated-vapor entropy (s_g) of 6.6 kJ kg^{-1} K^{-1}. The system is **now heated** up to 350°C by adding heat from a reservoir at 350°C, without changing the mass on the piston. At 1000 kPa and 350°C water is a superheated-vapor and has an enthalpy (h) of 3158 kJ kg^{-1} and entropy (s) of 7.3 kJ kg^{-1} K^{-1}. (Lowercase represent the specific values).

i. Using the result in part-(a), find the heat transfer $Q_{in}(1 \rightarrow 2)$ to the control-mass during the complete process using enthalpy.

(05 marks)

ii. By finding the relevant area for the process in the T-s diagarm, find the heat transfer $Q_{in}(1 \rightarrow 2)$ to the control-mass during the complete process. (assume the line from g to 2 in the diagram is linear.)

(05 marks)

iii. Write down the entropy equation for a thermal process. Then using the result in (b)-(i), find the total entropy generation (S_{gen}) due to the complete process.

(05 marks)

iv. After reaching the final temperature at 350°C, the process is reversed to its initial state by removing heat to a reservoir at 180°C. Using the entropy equation, find the total entropy generation (S_{gen}) due to this reversed-process.

(05 marks)

5. (a) Using $Tds = du + Pdv$ and $du = C_v dT$, show that $dS = m[C_v(\frac{dT}{T}) + R(\frac{dv}{v})]$ for an ideal gas of mass m. Hence assuming that C_v is independent of temperature, show that the change in entropy of the gas for a process changing from state-1 to state-2 is given by

$$\Delta S = m\left[C_v\, ln\left(\frac{T_2}{T_1}\right) + R\, ln\left(\frac{v_2}{v_1}\right)\right]$$

(Here R is the individual gas constant of the ideal gas. Lowercase represent the specific values.)

(08 marks)

(b) If the change from the state-1 to state-2 in part (a) is done by a reversible isothermal process, then

i. Using the result in part-(a), find the change in entropy $((\Delta S)_T)$ inof the gas. What is the entropy generation (S_{gen}) during the process?.

Then using the entropy equation find the entropy exchange (S_{in}) in to the gas.

(08 marks)

ii. Find the work done $W(1 \to 2)$ by the gas. What is the change in internal energy (ΔU) of the gas?.

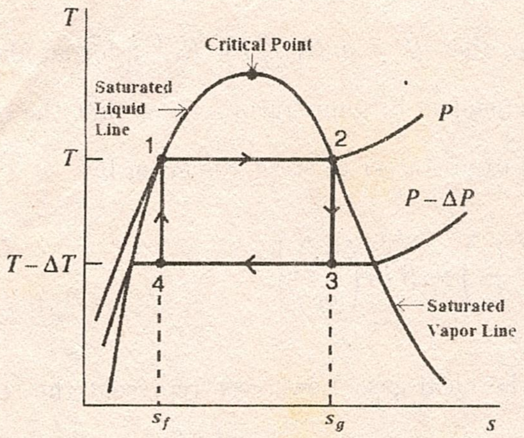
Then using the energy equation, find the heat exchange $Q_{in}(1 \to 2)$ to the gas.

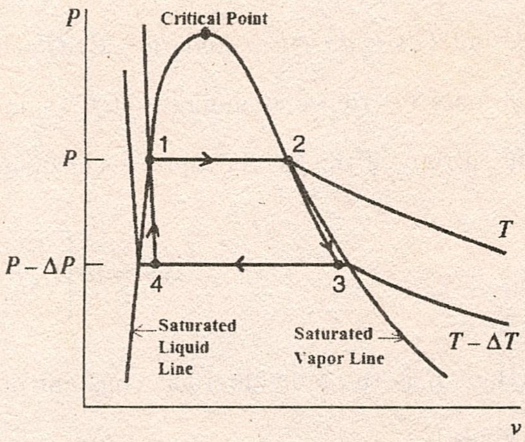
(06 marks)

(c) If the process was done by a reversible adiabatic process from the state-1 to the state-2 then using the entropy equation show that this process is an isentropic process.

(03 marks)

6. The T-s and P-v diagrams shown below are for a Carnot heat engine that uses a working fluid in a piston/cylinder combination. At T and P the fluid changes from saturated liquid to saturated vapor due to heat addition and the heat removal process occurs at a lower temperature and a pressure of $(T - \Delta T)$ and $(P - \Delta P)$, respectively.





(a) Using the T-s diagram, obtain expressions for the heat exchange to the working fluid and heat exchange from the working fluid during the two isothermal processes seperately. **Hence**, show that the net work done w_{net} by the fluid during the cycle is given by $w_{net} = \Delta T(s_g - s_f)$.

(Lower case indicate specific values).

(05 marks)

(b) Using the P-v diagram, find the work done by **each** of **four** processes during the cycle **separately**. (Assume the linearity of the lines in the diagram).

(10 marks)

(c) Adding the four results in part-(b), show that the net work done (w_{net}) is given by $w_{net} = \frac{\Delta P}{2}[v_3 + v_2 - v_4 - v_1]$. **Hence** show that $w_{net} = \Delta P(v_g - v_f)$, taking the limits $v_4 \rightarrow v_1 = v_f$ and $v_3 \rightarrow v_2 = v_g$.

(10 marks)

Part B

7. A point particle of mass m moves under a helical potential given by

$$U(\rho, \phi, z) = v_0 \rho \cos(\phi - \frac{2\pi z}{b})$$

where b and v_0 are positive constants and ρ, ϕ and z are cylindrical coordinates of the particle.

(a) Write down the Lagrangian for the particle choosing (ρ, ϕ, z) as generalized coordinates

(15 marks)

(b) Obtain the equations of motion of the particle (10 marks)

8. An object of mass m moves under the influence of a central potential

$$U = kr^{\frac{1}{4}}$$

(a) Show that the angular momentum, l of the object is conserved.

(06 marks)

(b) Obtain an expression for the effective potential of the system.

(06 marks)

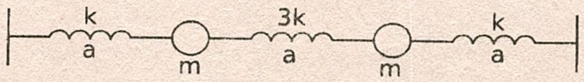
(c) For what value of radius, r, does a circular orbit exist?

(08 marks)

(d) Is the circular orbit stable or unstable?

(05 marks)

9. Two identical masses of mass m each are connected to two rigid walls with three springs of negligible mass and unstetched length a for each as shown in the following diagram. The force constants of springs are marked on the figure.



For small horizontal oscillations of the system, find

(a) the eigen-frequencies and

(17 marks)

(b) the normal modes of vibration

(08 marks)