[This question paper contains 6 printed pages.]

3079 *Your Roll No.* .....

MEM **J**

Paper – ME.552

THERMODYNAMICS

Time : 3 Hours *Maximum Marks : 100*

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt any **five** *questions.*
All *questions carry equal marks.*
Assume suitably missing data, if any.

Use of various property tables and charts are permitted.
For Air, $C_p = 1.005$ *KJ/Kg-K,* $\gamma = 1.4$.

1. (a) A gas of mass 1.5 kg undergoes a quasi-static expansion which follows a relationship p = a + bV where a and b are constants. The initial and final pressures are 1000 KPa and 200 KPa respectively and the corresponding volumes are 0.20 m^3 and 1.2 m^3. The specific internal energy of the gas is given by the relation

$$u = 1.5\ pv - 85\ KJ/Kg$$

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where p is in KPa and v is in m^3/kg. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion. (10)

(b) The air speed of a turbojet engine in flight is 900 Km/hr. Ambient air temperature is 1°C (enthalpy of air at 1°C = 5 KJ/Kg) and gas temperature leaving the turbojet is 400°C (enthalpy of gas at 400°C = 400 KJ/Kg). The air fuel ratio is 50:1. The calorific value of fuel is 45,000 KJ/Kg. 5% of the chemical energy is not released due to in complete combustion. Heat loss from the engine is 20 KJ/Kg of air. Calculate the thrust power of jet if the air flow rate is 5 Kg/s. (6)

(c) Differentiate clearly between steady flow and unsteady flow. (4)

2. (a) How a reversible process only a limiting process, never to be attained in practice. Also describe the reasons which makes process reversible. (3)

(b) Two carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000 K and 100 K respectively. Engine A receives 1680 KJ of heat from the high temperature reservoir and rejects heat to carnot engine B.

Engine B takes in heat rejected by engine A and rejects heat to the low temperature reservoir. If engine A and B have equal thermal efficiencies, determine

(i) the heat rejected by engine B

(ii) the temperature at which heat is rejected by engine A

(iii) the work done during the process by engines, A and B respectively.

If the engine deliver equal work, determine

(iv) the amount of heat taken in by engine B

(v) the efficiencies of engines A and B. (12)

(c) Prove that COP of a reversible refrigerator operating between two given temperature is maximum. (5)

3. (a) How did Rudolf Clausius summarize the first and second laws of thermodynamics. (2)

(b) Determine the maximum work obtainable from two finite bodies at temperature T_1 and T_2. (5)

(c) Two vessels, A and B, each of volume 3 m^3 may be connected by a tube of negligible volume. Vessel A contains air at 0.7 MPa, 95°C, while Vessel B contains air at 0.35 MPa, 205°C. Find the change of entropy when A is connected to B by working from the first principles and assuming the mixing to be complete and adiabatic. (10)

(d) The amount of entropy generation quantifies the intrinsic irreversibility of a process. Explain. (3)

4. (a) Define second law efficiency. Derive an expression for second law efficiency for a heat pump. (3)

(b) Energy is always conserved, but its quality is always degraded. Explain. (3)

(c) A lead storage battery used in an automobile is able to deliver 5.2 MJ of electrical energy. This energy is available for starting the car. Let compressed air be considered for doing an equivalent amount of work in starting the car. The compressed air is to be stored at 7 MPa, 25°C. What is the volume of the tank that would be required to let the compressed air have an availability of 5.2 MJ ? (14)

5. Starting from basics, derive the following relations.

(a) $U = F - T\left(\frac{\partial P}{\partial T}\right)_V = -T^2\left(\frac{\partial F/T}{\partial T}\right)_V$

(b) $C_P = -T\left(\frac{\partial^2 G}{\partial T^2}\right)_P$

(c) $C_v = -T\left(\frac{\partial p}{\partial T}\right)_v \left(\frac{\partial V}{\partial T}\right)_S$

(d) $\frac{(\partial p/\partial T)_S}{(\partial p/\partial T)_v} = \frac{\gamma}{\gamma - 1}$ (5×4=20)

6. (a) Liquid ethanol (C_2H_5OH) is burnt with 150% theoretical oxygen in a steady flow process. The reactants enter the combustion chamber at 25°C, and the products are cooled and leave at 65°C, 0.1 MPa. Calculate the heat transfer per kg mole of ethanol. The enthalpy of formation of $C_2H_5OH(l)$ is –277.634 KJ/Kg-mol. (10)

(b) What are the four types of equilibrium ? What is meant by neutral and unstable equilibrium ? (4)

(c) Starting from basics, prove that internal energy is a function of temperature only. (6)

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7. Write comprehensive short notes on following :

(a) Generalized compressibility chart and reduced variables

(b) Fugacity and activity

(c) Clausius-Clapeyron equation (20)