[This question paper contains 4 printed pages.]

Your Roll No. .....

3187 **J**

MEM

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.

For Air, $C_p = 1.005$ *kJ/kg-K,* $r = 1.4$.

Use of various properly tables and charts are permitted.

1. (a) In a power cycle, air is isothermally compressed. Heat is then added at constant pressure, after which the air expands isentropically to its original state. Draw the cycle on P-V and T-S coordinates. Show that the cycle efficiency can be expressed in the following form : 12

$$\eta = 1 - \frac{(\gamma - 1)\ln r}{\gamma\left[r^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

where r is the pressure ratio, $\frac{p_2}{p_1}$

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Determine the pressure ratio and the cycle efficiency if the initial temperature is 27°C and maximum temperature is 327°C. 12

(b) A diffuser has air entering at 100 kPa, 300 K with a velocity of 200 m/s. The inlet cross sectional area of the diffuser is 100 mm^2. At the exit, the area is 860 mm^2, and the exit velocity is 20 m/s. Determine the exit pressure and temperature of the air. 5

(c) Portable electric heaters are commonly used to heat small rooms. Explain the energy transformation that takes place. 3

2. (a) A heat pump with a COP of 2.4 is used to heat a house. When running, the heat pump consumes 8 kW of electric power. If the house is losing heat to outside at an average rate of 40000 kJ/h and the temperature of the house is 3°C when the heat pump is turned on, determine how long it will take for the temperature in the house to rise to 22°C. Assume the house is well insulated and take the entire mass within the house to be equivalent to 2000 kg of air. 9

(b) Two blocks of metal, each having a mass of 10 kg and specific heat of 0.4 kJ/kg-K, are at a temperature of 40°C. A reversible refrigerator receives heat from

one block and rejects heat to other. Calculate the work required to cause a temperature difference of 100°C between the two blocks. 8

(c) Show that the heat transfer through finite temperature difference is irreversible. 3

3. (a) 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 principle and assuming the mixing to be complete and adiabatic. 10

(b) 80 kg of water at 100°C are mixed with 50 kg of water at 60°C, while the temperature of surrounding is 15°C. Determine the decrease in available energy due to mixing. 7

(c) What do you understand by dead state ? 3

4. (a) Air flows through an adiabatic compressor at 2 kg/s. The inlet conditions are 1 bar and 310 K and the exit conditions are 7 bar and 560 K. Compute the net rate of availability transfer and the irreversibility. 8

(b) A gasoline engine delivers 150 kW. The fuel used is $C_8H_{18}(l)$ and it enters the engine at 25°C. 150% theoretical air is used and it enters at 45°C. The

product of combustion leave the engine at 750 K, and the heat transfer from the engine is 205 kW. Determine the fuel consumption per hour, if complete combustion is achieved. 12

5. Starting from basics, derive the following thermodynamic relations : 4×5 = 20

(a) $C_P - C_V = - T \left(\frac{\partial V}{\partial T}\right)_p^2$

(b) for a van der Waal's gas $\left(\frac{\partial C_V}{\partial v}\right)_T = 0$

(c) $H = - T^2 \left(\frac{\partial G/\partial T}{\partial T}\right)_p$

(d) $\left(\frac{\partial h}{\partial p}\right)_T = -T^2 \left(\frac{\partial (v/T)}{\partial T}\right)_p$

6. Nitrogen is passed through a throttling value from 10 MPa and 180 K to 0.6 MPa. As the gas passes through a very small length, the temperature of the gas is found as 120 K. Evaluate the heat transfer and entropy change using generalized charts. Given P_C = 3.39 MPa and T_C = 126.2 K. 20

7. Write short notes on following : 20

(i) Lost Work

(ii) Second Law Efficiency

(iii) Adiabatic Flame Temperature.