| CSM – 55/17 |
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| **Mechanical Engineering** |
| **Paper – II** |

*Time : 3 hours*

*Full Marks : 300*

*The figures in the right-hand margin indicate marks.*

*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any **three** of the remaining questions selecting at least **one** from each Section.*

## SECTION – A

1. Answer any **three** of the following :

   (a) Define the following terms : 20

   Thermodynamic System, Control volume, Intensive properties, Non-flow process, Steady flow process, Universal gas constant, Free expansion, Quasi static process.

(b) A heat pump working on a reversed Carnot cycle takes energy from a reservoir maintained at 278 K and deliver it to another reservoir where temperature is 350 K. The heat pump drives power for its operation from a reversible engine operating within the higher and lower temperature limits of 1350 K and 350 K. For 100 kJ/s of energy supplied to the reservoir at 350 K. Also, calculate COP for the heat pump. What would be the COP of a corresponding refrigerator working within the same temperature limit ? For refrigerator 100 kJ/s is to be extracted from the body being cooled. 20

(c) A perfect gas undergoes a cycle comprise of three process. It is first compressed isothermally from 1 bar, $27^{o}$ C to one eighth of its initial volume. Energy is then added at constant pressure increasing the temperature of gas and the cycle is completed by a reversible adiabatic expansion to the original condition.

Sketch the cycle on a P-V diagram, calculate the maximum cycle temperature and pressure and find the network transfer per kg of gas.

Assume $C_p$ = 1.25 kJ/kg K, R = 0.5 kJ/kg K 20

(d) What is the required wattage of an electrical heater that heats 0.1 $m^3$/s of air from 15°C and 80% RH to 55°C ? The barometric pressure is 101.325 kPa. 20

2. (a) A two cylinder single acting air compressor is to deliver 16 kg of air per minute and the index for both compression and expansion as 1.3. Compressor is directly coupled to a four cylinder four stroke petrol engine which runs at 2000 rpm with a brake mean effective pressure of 5.5 bar. Assume stroke bore ratio 1.2 for both engine and compressor, for compressor efficiency of 82% calculate cylinder dimensions. 30

(b) A 50 kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45 kJ/kg. K for the iron, determine : 30

(a) The entropy change of the iron block.

(b) The entropy change of the lake water.

(c) The entropy generated during this process.

3. (a) An air flow of 5 kg/min at 1500 K, 125 kPa goes through a constant pressure heat exchanger, giving energy to a heat engine. The air exits at 500 K and the ambient is at 298 K, 100 kPa. Find the rate of heat transfer delivered to the engine and the power the engine can produce. 30

(b) A 3-mm-diameter and 5-m-long electric wire is tightly wrapped with a 2-mm thick plastic cover whose thermal conductivity is k = 0.15 W/m °C. Electrical measurements indicate that a current of 10 Amp passes through the wire and there is a voltage drop of 8 Volts along the wire. If the insulated wire is exposed to a medium at $T = 30^{o}C$ with a heat transfer coefficient of $h = 12\ W/m^2\ {}^{o}C$, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also, determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature. 30

4. (a) The reduced ambient air refrigeration system is used for an aircraft moving with 1500 kmph. Ambient conditions are $10^{o}C$ and 0.8 bars. Rammed air expanded in first cooling turbine up to 0.8 bars. Air bled from main compressor at 6 bars is cooled in the heat exchanger and leaves at $100\ {}^{o}C$. Cabin is maintained at $20^{o}C$ and 1 bar. Pressure loss between second cooling turbine and cabin is 0.1 bar. Assume ram, compressor & cooling turbine efficiency as 90%, 85%, 80% respectively. Determine Mass rate of air supplied to cabin if cabin load is 10 tone of refrigeration and COP of the system. 30

(b) An ammonia based refrigeration system with a refrigeration capacity of 100 TR operates at an evaporating temperature of $-36^{\circ}C$ (saturation pressure = 0.8845 bar) and a condensing temperature of $30^{\circ}C$ (saturation pressure = 11.67 bar). Assume the system to operate on a single stage saturated (SSS) cycle. The compression process may be assumed to be isentropic. Under these conditions take Enthalpy of saturated vapour at the exit of evaporator = 1414 kJ/kg, Enthalpy of saturated liquid at the exit of condenser = 341.8 kJ/kg and Isentropic index of compression, $\gamma = 1.304$.

The compressor is an 8-cylinder, reciprocating type with a clearance ratio of 0.05 and speed of 1750 RPM. The stroke-to-bore ratio is 0.8. In the absence of superheat data, the refrigerant vapour may be assumed to behave as a perfect gas. The molecular weight of ammonia is

17.03 kg/kmol. Determine (a) Power input to the compressor, (b) COP and cycle (second law) efficiency and (c) Compressor discharge temperature. 30

## SECTION – B

5. Attempt any **three** of the following :

   (a) Write the main functions of an injection pump ? Give a brief account of injection of fuel in a S. I. engine. 20

   (b) With a neat sketch, write the principle of operation of a two stroke engine. 20

   (c) Discuss the different factors those affect the cost of power generation ($kWh_{net}$). 20

   (d) Explain the Fanno line and Rayleigh line flows. What are the inferences drawn from the analysis of the two types of flows ? 20

6. (a) Discuss the process of formation of CO, $NO_X$ and UBHC during the combustion of fossil fuels in any engine / power plant. Explain the methods of measuring the above pollutants and their control. 30

   (b) Following results are obtained from a test on a single cylinder, four stroke engine having a bore of 15 cm and stroke of 27 cm. Speed 300 rpm, brake torque 200 N-m, indicated mean effective pressure 6 bar, fuel consumption 2.2 kg/hr, cooling water flows 5 kg/min and its rise in temperature is 35°C, A/F ratio 22, exhaust gas temperature is 410°C, barometric pressure 1 bar, room temperature 27°C. The fuel has a calorific value of 42 MJ/kg and contains 15% by weight of Hydrogen. Assuming latent heat of vapourisation as 2300 kJ/kg, determine (a) the indicated thermal efficiency, and (b) the volumetric efficiency based upon atmospheric conditions. Draw a heat balance in terms of kJ/min.

$C_p$ of dry exhaust gas and super heated steam are 1.0 kJ/kgK and 2.1 kJ/kgK respectively, R = 0.287 kJ/kgK. 30

7. (a) Draw a neat schematic diagram of a thermal power plant showing the relative positions of the boiler accessories. Discuss briefly, how do they increase the efficiency of a thermal power plant. 20

(b) Describe the working principle of a electrostatic precipitator and discuss the advantages and disadvantages of it. 20

(c) A chimney is used to produce a draught for a boiler which has a average coal consumption of 2000 kg/hr and flue gases formed are 14.5 kg/kg of fuel. The pressure losses through the system are as follows :

Pressure loss in the fuel bed 7 mm of water,
Pressure loss in the boiler flues 7 mm of water,
Pressure loss in the bends 3 mm of water,
Pressure loss in the chimney 3 mm of water.

Pressure head equivalent to velocity of flue gases passing through the chimney 1.5 mm of water.

The temperature of ambient air and flue gases are 33°C and 333°C respectively. Assume actual draught is 80% of theoretical.

Determine the height and diameter of a chimney. 20

8. (a) The conditions of air at the entry of an axial compressor stage are $p_1$ = 768 mm of Hg,

$T_1$ = 314 K. The air angles in absolute systems are $\alpha$ and in relative systems are $\beta$. $\beta_1 = 51^\circ$, $\beta_2 = 9^\circ$, $\alpha_1 = \alpha_3 = 7^\circ$ where subscripts 1 and 2 are rotor entry and exit respectively and 3 is stator exit. The mean diameter and peripheral speed are 60 cm and 110 m/s. Mass flow rate through the stage is 25 kg/s. The work done factor is 0.95 and $\eta_{mech}$ is 92%. Assuming an $\eta_{stage}$ is 85%, determine (a) air angle at the stator entry, (b) blade height at entry and the hub-tip diameter ratio, (c) stage loading coefficient, (d) stage pressure ratio and (e) the power required to drive the stage. 30

(b) From the first principle derive the momentum integral equation for an incompressible laminar fluid flow over a flat plate 30