[This question paper contains 4 printed pages]

Roll No.	

ASME-24BC-MENG-II

MECHANICAL ENGINEERING (PAPER-II)

Time Allowed: 3 Hours [Maximum Marks: 100

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read the following instructions carefully before attempting questions.

1. There are EIGHT questions printed in English.
2. Candidate has to attempt FIVE questions in all.
3. Question No.1 is compulsory. Out of the remaining SEVEN questions, FOUR are to be attempted.
4. All questions carry equal marks. The number of marks carried by a question / part are indicated against it.
5. Write answers in legible handwriting.
6. Wherever any assumptions are made for answering a question, they must be clearly indicated.
7. Diagrams / Figures, wherever required, shall be drawn neatly. Unless otherwise mentioned, symbols and notations carry their usual standard meanings.
8. Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in answer book must be clearly struck off.
9. Re-evaluation / Re-checking of answer book of the candidate is not allowed.
10. Use of calculators is allowed.

1. (a) Explain the significance of the Carnot refrigeration cycle in thermodynamics. Discuss the limitations of real-world refrigeration systems when compared to the ideal Carnot cycle. 05

(b) Define the laws of thermodynamics and discuss their significance in engineering and scientific applications. 05

(c) A pump is used to raise water from a lower reservoir to a higher reservoir. The flow rate of water is 0.05 m^3/s, and the height difference is 15 meters. Additionally, the water temperature is 40°C, where the density of water is 990 kg/m^3, and the acceleration due to gravity is 9.81 m/s^2. Calculate the power required by the pump assuming an isentropic efficiency of 75%. Also, consider the pump's dynamic head loss to be 5 meters due to friction. 05

(d) Derive the expression for the work done during the isothermal expansion of an ideal gas and explain the underlying assumptions. Then, using the derived formula, calculate the work done by the gas when it expands from 4 litres to 12 litres at a constant temperature of 300 K and an initial pressure of 2 atm. Assume gas constant to be 0.082 L·atm/(mol·K). 05

2 (a) (a) Derive the energy equation for a control volume with compressible fluid flow. Consider the effects of kinetic energy, potential energy, heat transfer, and work done, including compressibility effects. Assume the control volume has varying properties with temperature-dependent specific heats. 07

(b) Discuss the concept of entropy in the context of steam turbines. Explain how entropy generation impacts the efficiency of steam turbines and the significance of using steam tables for calculating the properties of steam during expansion. 07

(c) A heat exchanger transfers 1000 kJ/hr of heat from a hot fluid to a cold fluid. The hot fluid enters at 90°C and exits at 60°C, while the cold fluid enters at 20°C and exits at 40°C. Determine the effectiveness of the heat exchanger assuming a counterflow arrangement. 06

3. (a) Explain Bernoulli's equation and discuss its practical applications in fluid dynamics 08

(b) A fluid with a density of 1200 kg/m^3 flows through a pipe with a diameter of 0.2 m and flow velocity of 5 m/s. The dynamic viscosity of the fluid is a function of temperature, given by $\mu(T)=0.001\cdot(1+0.02\cdot(T-20))$, where T is the temperature in °C. 12

Calculate the Reynolds number at two temperatures: 30°C and 40°C. Determine if the flow is laminar or turbulent at these temperatures. Calculate Reynold number at 30 °C, at 40 °C and flow regime.

4. (a) A composite wall is constructed from three materials with thermal conductivities k_1=1.5W/m·K, k_2=0.5W/m·K, and k_3=2.0W/m·K. The thicknesses of the layers are $L1$=0.1m, $L2$=0.2m, and $L3$=0.15m respectively. The wall is subjected to a steady-state heat conduction process with a temperature difference of 100°C between the inner and outer surfaces. Calculate overall heat transfer rate and temperature at interfaces — 08

(b) Explain the working principles of the Brayton cycle. — 04

(c) Calculate the temperature at the compressor and turbine exit and the network output for a gas turbine operating on Brayton cycle with a pressure ratio of 8:1, an isentropic efficiency of 85% for the compressor, and 90% for the turbine. The inlet conditions to the compressor are 300 K and 100 kPa. Assume the working fluid is air with constant specific heats. Consider Cp = 1.005 kJ/kg·K and specific heat ratio (γ) = 1.4 — 08

5. (a) Distinguish between Knocking and Detonation. — 04

(b) Discuss the significance of using refrigerants like R-22 in refrigeration systems. Explain the factors affecting the COP of a refrigeration system. — 06

(c) A crossflow heat exchanger uses water to cool air. The water enters the heat exchanger at 90°C and leaves at 70°C. The air enters at 30°C and leaves at 60°C. Given that the mass flow rate of water is 2 kg/s and the mass flow rate of air is 1.5 kg/s, calculate the effectiveness of the heat exchanger. Assume the specific heat capacities of water and air are 4.18 kJ/kg·K and 1.005 kJ/kg·K, respectively. — 10

6. (a) Derive the Navier-Stokes equation for incompressible flow considering both laminar and turbulent flow regimes. Explain the implications of the equations in different flow regimes and discuss their significance in predicting fluid behaviour. Use appropriate assumptions and simplifications for the derivation. — 07

(b) Discuss the role of surface roughness and variable heat transfer coefficients in convective heat transfer. Consider a rectangular plate of dimensions 2 m x 3 m maintained at a temperature of 90°C, exposed to ambient air at 20°C. Calculate the total rate of heat loss due to convection, assuming the heat transfer coefficient is given by $h=50+0.1\cdot(T_{plate}-T_{ambient})$ W/m²K. — 07

(c) A refrigeration cycle operates with an ideal gas as the refrigerant. The cycle involves a compressor, a condenser, an expansion valve, and an evaporator. The working conditions and properties of the refrigerant are as follows: 06

- **Compressor Inlet:** Pressure P_1=1 bar, Temperature T_1=10°C
- **Compressor Outlet:** Pressure P_2=8 bar, Temperature T_2=50°C
- **Condenser:** Pressure P_3=8 bar, Temperature T_3=40°C (constant pressure)
- **Expansion Valve:** Pressure P_4=1 bar, Temperature T_4 = 10°C

Calculate Enthalpy change across the compressor, coefficient of performance and work input required for the compressor.

7. (a) What do you understand by air pollution and its sources? Discuss the prevention strategies for air pollution. 06

(b) Explain the concept of heat exchanger effectiveness and derive the formula for calculating the effectiveness of a parallel flow heat exchanger. 06

(c) In a vapor-compression refrigeration system, a refrigerant undergoes isentropic compression from an initial pressure of 1.5 bar to a final pressure of 7.5 bar. The specific enthalpy of the refrigerant at the compressor inlet and outlet is 260 kJ/kg and 310 kJ/kg respectively and the temperature at the inlet is 10°C. Assuming an ideal gas behavior for the refrigerant, calculate the work done per kg of refrigerant. Also, determine the coefficient of performance (COP) of the system if the heat absorbed from the evaporator is 180 kJ/kg. 08

8. (a) What is the Log Mean Temperature Difference (LMTD), and why is it important in heat exchanger design? 05

(b) What is the Number of Transfer Units (NTU), and how is it used to characterize heat exchanger performance? 05

(c) A piston-cylinder assembly contains an ideal gas undergoing a polytropic process described by PV^n=constant. The gas expands from an initial state of 2 L and 400 K to a final volume of 6 L. The initial pressure is 3 ATM, and the process is polytropic with n=1.2. Calculate the work done by the gas during this expansion, the final temperature, and the change in internal energy. Assume that the specific heat capacities are Cp=1.0kJ/kg·K and Cv=0.7kJ/kg·K. 10

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