Total No. of Printed Pages—7

4CCSME

MECHANICAL ENGINEERING

PAPER—II

Full Marks : 200   *Time* : 3 hours

The figures in the margin indicate full marks

Candidates should answer **five** questions out of **ten** questions. Question No. **1** is compulsory

1. Answer any *four* questions of the following *eight* : 10×4=40

(a) Define internal energy. Show that internal energy is a property of a system.

(b) A fluid contained in a cylinder receives 150 kJ of mechanical energy by means of paddle wheel, together with 50 kJ in the form of heat. At the same time, a piston in the cylinder moves in a way that the pressure remains constant at 200 kN/m^2 during the fluid expansion from $2m^3$ to $5m^3$. What is the change in internal energy and in enthalpy?

(c) The barometric pressure at sea level is 760 mm of Hg while that on a mountain top is 735 mm. If the density of air is assumed constant at 1·2 kg/m^3, what is the elevation of the mountain top?

(d) A two-dimensional flow field is given by $\phi = 3xy$, determine the velocity at $L(2, 6)$ and $M(6, 6)$ and the discharge between the streamlines passing through the points L and M.

(e) State the conditions for a process to be reversible.

(f) State the conditions necessary for a substance to be defined as perfect gas. How does it differ from ideal gas?

(g) Write the steady flow energy equation and point out the significance of various terms involved.

(h) How would you distinguish between hydrodynamically smooth and rough boundaries?

2. (a) When the system is at equilibrium, why would any conceivable change in entropy be zero? Show that the transfer of heat through a finite temperature difference is irreversible. 10

(b) A Carnot engine with a fuel burning device as source and a heat sink cannot be treated as a reversible plant. Explain. 10

(c) A heat engine receives half of its heat supply at 1000K and half at 500K while rejecting heat to a sink at 300K. What is the maximum thermal efficiency of the heat engine? 20

10. (a) In a hydroelectric station, water is available at the rate of 175 m^3/s under a head of 18 m. The turbines run at a speed of 150 r.p.m. with overall efficiency of 82%. Find the number of turbines required if they have the maximum specific speed of 460. 10

(b) With suitable sketch, explain the working principle of nuclear power plant. What are their advantages of limitations? 10

(c) A classroom of 60-seating capacity is air-conditioned. The outdoor conditions are 32 °C DBT and 22 °C WBT and required comfort conditions are 22 °C DBT and 55% RH. The quantity of outdoor air supplied is 0·5 m^3/min/student. The comfort conditions are achieved first by chemical dehumidifying the air and then cooling by the cooling coil. Find —

(i) DBT of the air leaving the dehumidifier ;

(ii) capacity of the humidifier and cooling coil. 20

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The pump feedsback the water into the boiler. If the turbine and pump have each 80% efficiency, find the net work per kg of steam and the cycle efficiency. 20

9. *(a)* State elements of refrigeration system. What is a standard rating of a refrigeration system? Show the simple vapour compression refrigeration cycle on *p–h* chert. 10

(b) An air-water vapour mixture at 25 °C and 1 bar has a relative humidity of 75%. Determine the specific humidity and dew point temperature. Also find the amount of water vapour condensed, if the mixture is cooled to 10 °C at constant pressure. 10

(c) A refrigerator operating on standard vapour compression cycle has a COP of 6·5 and is driven by a 50 kW compressor. The enthalpies of saturated liquid and saturated vapour refrigerant at the condensing temperature of 35 °C are 62·55 kJ/kg and 201·45 kJ/kg respectively. The saturated refrigerant vapour leaving evaporator has an enthalpy of 187·53 kJ/kg. Find the refrigerant temperature at compressor discharge. Take C_p of refrigerant vapour as 0·6155 kJ/kg-°C. 20

3. *(a)* For a steady laminar flow through a circular pipe, prove that the velocity distribution across the section is parabolic and the average velocity is half of the maximum local velocity. 20

(b) A plate 450 mm × 150 mm has been placed longitudinally in an oil of specific gravity 0·925 and kinematic viscosity $0{\cdot}9\times10^{-4}$ m^2/s which flows with velocity of 6 m/s. Calculate —

(i) the friction drag on the plate ;

(ii) boundary layer thickness at the trailing edge ;

(iii) shear stress at the trailing edge. 20

4. *(a)* How is sonic velocity defined in terms of pressure and density of the fluid? Show that for an ideal gas in an isentropic flow, the sonic velocity depends on the temperature and nature of the gas. 20

(b) In aircraft flying at an altitude where the pressure was 35 kPa and temperature –38 °C, stagnation pressure measured was 65·4 kPa. Calculate the speed of the aircraft. Take molecular weight of air as 28. 20

5. *(a)* A long steel rod, 22 mm in diameter, is to be heated from 420 °C to 540 °C. It is placed concentrically in a long cylindrical furnace which has an inside diameter of 180 mm. The inner surface of the furnace is at a temperature of 1100 °C and has an emissivity of 0·82. If the surface of the rod has an emissivity of 0·62, find the time required for the heating operation. Take C_p for steel=0·67 kJ/kgK and ρ =7845 kg/m^3. 20

(b) A current of 200 amperes is passed through a stainless-steel wire of 3 mm diameter having thermal conductivity (K) = 19 W/m. °C. The resistivity of the steel may be taken as 70 $\mu\Omega$.cm, and the length of the wire is 1 m. The wire is submerged in a liquid at 110 °C and experiences a convective heat transfer coefficient of 4 kW/m^2. °C. Calculate the centre temperature of the wire. 20

6. *(a)* Calculate the critical radius of insulation for asbestos [K=0·17W/m–°C] surrounding a pipe and exposed to room air at 20 °C with h=3 W/m^2. °C. Calculate the heat loss from a 200 °C, 5 cm diameter pipe when covered with critical radius of insulation and without insulation. 20

(b) An oil cooler for a lubrication system has to cool 1000 kg/hr of oil (C_p=2·09 kJ/kg–K) from 80 °C to 40 °C by using a cooling water flow of 1000 kg/hr at 30 °C. Give your choice for a parallel flow or counter flow heat exchanger, with reasons. Estimate the surface area of the heat exchanger, if the overall heat transfer coefficient is 24 W/m^2-K. 20

7. *(a)* Briefly explain the stages of combustion in SI engines elaborating the flame front propagation. Discuss also the various factors that influence the flame speed. 20

(b) A six-cylinder, four-stroke diesel engine develops 125 kW at 3000 r.p.m. Its brake specific fuel consumption is 200 gm/kWh. Calculate the quantity of fuel to be injected per cycle per cylinder. Specific gravity of the fuel may be taken as 0·85. 20

8. *(a)* Define the volumetric efficiency of a compressor. On what factors does it depend? Explain the advantages of multistage compression. 20

(b) Steam at 20 bar, 360 °C is expanded in a steam turbine to 0·08 bar. It then enters a condenser where it is condensed to saturated liquid water.