2021

MECHANICAL ENGINEERING

PAPER-II

Time Allowed — 3 Hours *Full Marks — 200*

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

Answers may be given either in ***English*** *or in* ***Bengali*** *but all answers must be in one and the same language. Any data if needed may be assumed, but it must be clearly mentioned.*

Answer *any five* questions.

1. (a) Explain the concept of PMM1 and PMM2 in thermodynamics. (6)

   (b) Air at 10°C and 80 kPa enters the diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of the diffuser is 0·4 m^2. The air leaves the diffuser with a velocity that is very small compared to the inlet velocity. Calculate the mass flow rate of air and the temperature of the air leaving the diffuser. (14)

   (c) Two reversible heat engines are arranged in series. Engine A rejects heat directly to engine B. Engine A receives 200 kJ of heat at 421°C from a source, while engine B recjects heat to a sink at temperature of 4·4°C. If the work output of engine A is twice that of engine B, find (i) the intermediate temperature between engine A and engine B, (ii) the efficiency of each engine and (iii) the heat rejected to the cold sink at 4·4°C. (20)

2. (a) What do you mean by principle of increase of entropy? (6)

   (b) Calculate the entropy change of the universe as a result of the following processes: (i) A copper block of 600gm mass with C_p of 150 J/kg-K at 100°C is placed in a lake of 8°C, (ii) The same block at 8°C is dropped from height of 100m into the lake and (iii) Two such blocks at 100°C and 0°C are joined together. (14)

   (c) A parallel flow heat exchanger is used to cool alcohol from 66°C to 40°C using water entering at 5°C. The flow rates of alcohol and water are 55,000 kg/hr and 40,000 kg/hr respectively. Calculate the exit temperature of water, heat transfer rate and the required surface area of the heat exchanger. Take overall heat transfer co-efficient, U = 580 W/m^2-K, c_p (alcohol) = 3760 J/kg-K and c_p (water) = 4180 J/kg-K.

   Will there be any change in the surface area requirement if a counter flow heat exchanger is used for this cooling purpose? If so, find it. (20)

3. (a) Define radiosity, irradiation and view factor in connection with radiation heat transfer. Two parallel infinite plane surfaces are maintained at 200°C and 300°C respectively. Determine the net rate of radiation heat transfer per unit area when (i) the two surfaces are black and (ii) when the two surfaces are gray having emissivity of 0·8. (7+15=22)

(b) The exterior wall of a house consists of 10·16 cm thick layer of common brick having thermal conductivity 0·7 W/m-K. There is a 3·8 cm thick layer of gypsum plaster with thermal conductivity 0·48 W/m-K. What thickness of loosely packed rockwool insulation (k = 0·065 W/m-K) should be added to reduce the heat loss through the wall by 80%. (18)

4. (a) What do you mean by Lower Heating Value (LHV) and Higher Heating Value (HHV) of a fuel? For what purpose Orsat apparatus is used? Explain its working principle. (4+2+4=10)

(b) Show that the humidity ratio of moist air can be expressed as $\omega = 0{\cdot}622\frac{p_v}{p - p_v}$, where p_v and p are the partial pressure of water vapour and atmospheric pressure respectively. (10)

(c) Consider an ideal Rankine cycle where steam at 20 bar, 360°C is expanded in a steam turbine to 0·08 bar. Then it enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. Find per kg of steam the net work and the cycle efficiency. Also, calculate the percentage reduction in the network and the cycle efficiency if the turbine and the pump have 85% efficiency. Use of steam table is allowed. (20)

5. (a) What do you mean by chemically correct air fuel ratio? In this connection, explain the terms : lean mixture and rich mixture and equivalence ratio. Sketch the variation of requirement of air fuel mixture of a SI engine over its entire operating range. Mark the different regimes of operation. (2+6+8=16)

(b) An engine working on Otto cycle has a volume of 0.5 m^3, pressure of 1 bar and temperature of 27°C at the start of the compression process. The pressure becomes 10 bar at the end of the compression stroke. If the heat addition during the isochoric process is 200 kJ, determine the clearance volume as percentage of swept volume, efficiency of the cycle and the mean effective pressure. If the engine is a 4 stroke one and runs at 400 rpm, calculate the power developed. Take, $\gamma = 1.4$ for air. (16)

(c) Explain the terms : Cetane number and Octane number of IC engine fuel. What is the approximate value of Cetane number for commercially available diesel? (6+2=8)

6. (a) State the advantages of centrifugal pump over reciprocating pump. Explain the working of a centrifugal pump with the help of a neat sketch. (6+10=16)

(b) What do you mean by eco-friendly refrigerants? Name a few of them. (3+3=6)

(c) A simple saturated vapour compression refrigeration system works between evaporator temperature of –10°C and condenser temperature of 30°C using R-134a as the refrigerant. Calculate the COP of the system. Also, calculate the mass flow rate of the refrigerant, suction volume and power per ton of refrigeration. The relevant properties of R-134a are given below. The specific heat of R-134a vapour may be taken as 1.044 kJ/kg-K. (18)

Temp	P_{sat}(bar)	V_g(m^3/kg)	h_f(kJ/kg)	h_g(kJ/kg-K)	S_f(kJ/kg-K)	S_g(kJ/kg-K)
–10	2.0052	0.09963	186.78	392.75	0.9509	1.7337
+30	7.7008	0.02667	241.65	414.94	1.1432	1.7149

7. (a) A circular plate 4.5m in diameter is submerged in water. Its greatest and least depths below the water surface are 3m and 1.5m respectively. Calculate the total force on the front face of the plate and the position of centre of pressure. (16)

(b) What do you mean by viscosity of a fluid? State the differences between dynamic viscosity and kinematic viscosity. What are their units in SI system? (2+4+2=8)

(c) Explain the flow velocity measurement principle at any point in a pipe by Pitot tube. (6)

(d) Derive an expression for head loss due to friction for pipe flow, in terms of coefficient of friction, pipe dimensions and flow velocity. (10)
