2019

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) What do you mean by quasi-static process? How will you define a thermodynamic process and a thermodynamic cycle? An imaginary engine receives heat and does work on a slowly moving piston at such a rate that the cycle of operation of 1kg of working fluid can be represented as a circle of 10cm diameter on a PV diagram on which 1cm = 300 kPa and 1cm = 0·1m^3/kg. How much work is done by each kg of the working fluid for each cycle of operation? If the heat rejected by the engine in a cycle is 2000 kJ per kg of working fluid, what would be its thermal efficiency?

(b) What do you mean by non-flow process and flow process? Derive the steady flow energy equation with single inlet and single outlet. State the assumptions made to derive this equation.

(c) A heat engine operating between two reservoirs at temperatures 600°C and 40°C drives a refrigerator operating between reservoirs at temperatures of 40°C and –15°C. The heat transfer to the heat engine is 2500 kJ and the net work output of the combined engine and refrigerator plant is 400 kJ. The efficiency of the heat engine and the COP of the refrigerator are each 40% of the maximum possible values. Estimate the heat transfer of the refrigerant from the cold reservoir and the net heat transfer to the reservoir at 40°C.

(d) What do you mean by the principle of increase of entropy? Show that the entropy change of the universe will be necessarily positive due to the mixing of two fluids initially at different temperatures. You may assume that the heat capacities of the two fluids are the same.

10+10+12+8=40

2. (a) Define fin efficiency and fin effectiveness. If a fin is thin and tip loss is negligible, show that the heat transfer from the fin is given by $Q = \sqrt{hPkA}\,(T_0 - T_\alpha)\tan h\,(ml)$, where the symbols have their usual meanings.

(b) An aluminium alloy fin, 3·5 mm thick and 25 mm long protrudes from a wall. The base is at 420°C and the surrounding temperature is 30°C. The heat transfer coefficient and the thermal conductivity of aluminium may be taken as 11W/m^2-K and 200W/m-K respectively. Calculate the heat loss and fin efficiency, if the heat loss from the tip is negligible.

(c) A 2·5 m long steam pipe having 50 mm diameter has been placed horizontally and exposed to still air at 25°C. If the temperature of the pipe wall is 295°C, determine the rate of heat loss from the pipe due to convection. The properties of air at 160°C are as follows:

$v = 30 \cdot 09 \times 10^{-6} m^2/s$, $k = 3 \cdot 64 \times 10^{-2}\ W/m - k$ and $Pr = 0 \cdot 682$.

The following correlation may be used for Nusselt number:

$Nu = 0 \cdot 53(Gr.Pr)^{0 \cdot 25}$ for $10^4 < Gr.Pr < 10^9$ (laminar flow) and

$Nu = 0 \cdot 13(Gr.Pr)^{0 \cdot 33}$ for $10^9 < Gr.Pr < 10^{12}$ (turbulent flow).

(d) What do you mean by monochromatic emissive power and total emissive power of a black body? Starting from Planck's law of black body radiation, derive Wien's displacement law. What is the importance of this law? 8+8+14+10=40

3. (a) What is the difference between dry bulb temperature and wet bulb temperature? How will you measure them? What type of air conditioning system is needed for very hot and humid weather? Show the whole process on the psychometric chart.

(b) The condenser temperature and the evaporator temperature of an ammonia ice plant are of 35°C and of –15°C respectively. The plant produces 5 tons of ice per day from water at 25°C to ice at –5°C. Ammonia enters the compressor as dry saturated vapour and leaves the condenser as saturated liquid. Determine

(i) the capacity of the refrigeration plant,
(ii) mass flow rate of the refrigerant,
(iii) discharge temperature of ammonia from the compressor,
(iv) power consumed by the compressor and
(v) COP of the plant.

Take, latent heat of ice = 335 kJ/kg; specific heat of ice = 1·94 kJ/kg-K; specific heat of water = 4·2 kJ/kg-K and specific heat of ammonia vapour = 2·8 kJ/kg-K.

Other relevant properties of ammonia refrigerant may be obtained from the following table:

Tem (°C)	h_f(kJ/kg)	h_g(kJ/kg)	s_f(kJ/kg-K)	s_g(kJ/kg-K)
–15	112·3	1426·0	0·457	5·549
+35	347·5	1471·0	1·282	4·930

(c) What do you mean by stoichiometric air-fuel ratio and equivalence ratio? For what purpose ORSAT apparatus is used? Explain its working principle. 13+15+12=40

4. (a) State the differences between black body and gray body. What are space resistance and surface resistance in radiative heat transfer? What do you mean by radiation shield? How does it reduce the heat transfer rate due to radiation between two bodies?

(b) A hot oil with heat capacity rate of 2500 W/K flows through a double pipe heat exchanger. It enters at 360°C and leaves at 300°C. Cold fluid enters at 30°C and leaves at 200°C. If the overall heat transfer co-efficient is 800 W/m^2-K, determine the heat exchanger area for

(i) parallel flow arrangement and
(ii) counter flow arrangement.

Draw also the corresponding temperature profiles for both the cases.

(c) For what purpose Bell-Coleman cycle is used? Derive an expression for the COP of this cycle. 16+14+10=40

5. (a) Draw the PV and TS diagrams of Otto cycle. Find an expression for the air standard efficiency of Otto cycle. Show that the efficiency of Otto cycle is greater than that of Diesel cycle for the same compression ratio.

(b) Explain with the help of a neat sketch the principle of operation of an accelerating pump as employed in a carburettor.

(c) A trial on a single cylinder 4-stroke diesel engine provides the following data:

Speed = 400 rpm; Brake Power = 100 kW; Brake mean effective pressure = 850 kPa; Brake specific fuel consumption = 0·335 kg/kWh; Calorific value of the fuel = 43·50 MJ/kg. If the stroke to bore ratio is 1·25 and the mechanical efficiency of the engine is 80%, determine the bore and stroke of the engine, the brake thermal efficiency, the indicated thermal efficiency and the indicated mean effective pressure.

16+8+16=40

6. (a) What do you mean by ideal fluid? Sate and explain Newton's law of viscosity. What is the difference between dynamic viscosity and kinematic viscosity?

(b) A square metal plant of 1·8 m side has a thickness of 1·8 mm and weight of 60 N. The plate has to be lifted through a vertical gap of 30 mm of infinite extent. The oil in the gap has a specific gravity of 0·95 and viscosity of 3 N-s/m^2. Calculate the force and power required to lift the plate at a constant speed of 0·12m/s.

(c) What is a Pitot tube? How does it measure the velocity of flow at any point in a pipe?

(d) A rectangular plate 1·2 m long and 0·6 m wide is submerged in an oil bath of specific gravity 0·8. The maximum and the minimum depths of the plate are 1·6 m and 0·75 m respectively from the free surface. Find the hydrostatic force on one face of the plate and the depth of the centre of pressure.

8+12+8+12=40

7. (a) Define the following dimensionless numbers and state their importance in fluid mechanics:

(i) Reynolds number,

(ii) Froude number,

(iii) Mach number and

(iv) Weber number

(b) State different losses associated with the flow of liquid through a pipe. Derive an expression for the head loss due to friction in terms of Darcy co-efficient of friction, dimensions of the pipe and flow velocity.

(c) An oil of specific gravity 0·8 is flowing through a pipe of 300 mm diameter and 800 m length at a rate of 0·45 m^3/s. Kinematic viscosity of the oil is 0·3 stoke. Calculate the head loss due to friction and the power required to maintain the flow.

(d) State the condition for a fluid flow of be irrotational. What is Euler's equation? Explain the concept of velocity boundary layer and thermal boundary layer.

8+12+10+10=40

8. (a) What advantages are obtained in using high pressure boiler in a thermal power plant? With the help of a neat sketch explain the working of a high pressure boiler.

(b) Steam at 20 bar and 360°C expands in a turbine to a pressure of 0·08 bar. It then enters a condenser where it is condensed to saturated liquid water. Then the pump feeds back the water to the boiler. Calculate the cycle efficiency and the power developed if steam flow rate is 25kg/s.

The cycle may be assumed to follow an ideal Rankine cycle. Steam table or Mollier diagram may be used to get the properties of steam.

(c) State the differences between impulse and reaction turbines in case of hydraulic turbines. Give examples of each case.

(d) Explain the principle used in forced and induced draught. How will you calculate the power required to run ID fan and FD fan? Explain why balanced draught is preferred over only forced draught or induced draught. 12+10+10+8=40
