CC/M/EXAM.
2020

MECHANICAL ENGINEERING

PAPER—II

Time : 3 hours] [Full Marks : 250

Note : Question Nos. **1** and **5** are compulsory and out of the remaining, any **three** are to be attempted choosing at least ONE question from each Section. The number of marks carried by a question/part is indicated against it.

SECTION—A

1. Answer *any* **five** of the following questions : 10×5=50

(a) Apply steady flow energy equation to a boiler and obtain a relation for heat transfer to the boiler.

(b) Derive the expression for work, when a system undergoes a polytropic process.

(c) Show the temperature variation along the length of a heat exchanger, when *(i)* hot and cold fluids flow in parallel and counter-flow fashion, *(ii)* steam condenses on the outside of a condenser tube with water flowing inside as coolant and *(iii)* hot fluid is used for evaporating another liquid.

(d) Prove with appropriate diagram and equation that entropy is a property.

(e) Show that for a diffuser, the change in kinetic energy manifests itself with change in enthalpy.

(f) Prove that for the same compression ratio, the Otto cycle is more efficient than the Diesel cycle.

(g) Explain with a suitable diagram, the wet and dry bulb psychrometer.

2. Answer the following questions :

(a) A turbine operates under steady flow conditions, receiving steam at the following conditions :

Pressure = 1·5 MPa
Temperature = 200 °C
Enthalpy = 3000 kJ/kg
Velocity = 33·3 m/s
Elevation = 3 m

The steam leaves the turbine at the following state :

Pressure = 25 kPa
Enthalpy = 2500 kJ/kg
Velocity = 100 m/s
Elevation = 0 m

Heat is lost to the surroundings at the rate of 0·3 kJ/s. If the rate of steam flow through the turbine is 0·6 kg/s, what is the power output of the turbine in kW? 20

(b) Explain the supersaturated or metastable flow of steam through a nozzle and state the significance of Wilson's line. 15

(c) Name the different high pressure boilers. Sketch and explain the working of any one of them. 15

3. Answer the following questions :

(a) An engine working on Diesel cycle has a compression ratio of 15 and fuel supply is cut off at 8% of stroke. If the engine has a relative efficiency of 50%, determine the fuel consumption per kWh. Assume that the fuel has a calorific value of 42000 kJ/kg. 20

(b) "The fuel after injection into combustion chamber undergoes several pre-combustion stages before it finally burns." Explain the stages. 15

(c) With a suitable diagram, explain the function of choke in the carburetor system in SI engines. 15

4. Answer the following questions :

(a) Air at 2 atm and 200 °C is heated as it flows at a velocity of 12 m/s through a tube with a diameter of 3 cm. A constant heat flux condition is maintained at the wall and the wall temperature is 20 °C above the air temperature all along the length of the tube. Calculate the heat transfer per unit length of the tube and the increase in bulk temperature of air over a 4 m length of the tube. Properties of air at 200 °C are $Pr = 0 \cdot 681$, $\mu = 2 \cdot 57 \times 10^{-5}$ kg/ms, $k = 0 \cdot 0386$ W/mK, and $c_p = 1 \cdot 025$ kJ/kgK. 20

(b) What do you mean by fouling of heat exchanger? How is it correlated to the overall heat transfer coefficient? What are the causes of fouling? 15

(c) Define effectiveness and NTU of heat exchanger. After expansion from a gas turbine, the hot exhaust gases are used to heat the compressed air from a compressor with the help of a cross-flow compact heat exchanger of 0·8 effectiveness. What is the number of transfer unit of the heat exchanger? 15

SECTION—B

5. Answer *any* **five** of the following questions : 10×5=50

(a) Define Bernoulli's energy principle. Derive Bernoulli's equation from Euler's equation of motion.

(b) Define energy, exergy and anergy with a suitable diagram. What is the law of degradation of energy?

(c) Sketch a two-shell pass, four-tube pass, reverse current heat exchanger. Label the different parts.

(d) What is meant by overlap in a valve timing diagram? Give reasons for its use and mention any possible disadvantages.

(e) The average Nusselt number in laminar natural convection from a vertical wall at 180 °C with still air at 20 °C, is found to be 48. If the wall temperature becomes 30 °C, all other parameters remaining the same, what will be the average Nusselt number?

(f) The chlorofluorocarbon as refrigerant has been gradually eliminated from the refrigeration system. Explain why.

(g) What are wet-bulb depression and dew-point depression? Show both in T-s diagram.

6. Answer the following questions :

(a) Find the required air-fuel ratio in a gas turbine whose turbine and compressor efficiencies are 85% and 80% respectively. Maximum cycle temperature is 875 °C. The working fluid can be taken as air with $c_p = 1 \cdot 00$ kJ/kg K and $\gamma = 1 \cdot 4$. The air enters the compressor at 1 atm and 27 °C. The pressure is 4 atm. The fuel used has a calorific value of 42000 kJ/kg. There is a loss of 10% calorific value in the combustion chamber. 20

(b) Derive a mathematical expression for maximum work in Brayton cycle as a function of maximum and minimum cycle temperatures. 15

(c) Discuss the means for improving the efficiency and specific output of a gas turbine working on simple Brayton cycle. 15

7. Answer the following questions :

(a) 100 kg of water at 100 °C is mixed with 50 kg of water at 50 °C, while the temperature of the surrounding is 17 °C. Determine the decrease in available energy due to mixing. Take c_p of water as 4·186 kJ/kgK. 20

(b) Define entropy and availability. Draw an analogy between the two. 5+10=15

(c) Set up an expression for available energy for a finite energy source of varying temperature when the ambient temperature is T_0. 15

8. Answer the following questions :

(a) A standard vapour compression refrigeration cycle using F-12 as the refrigerant operates between the condenser pressure of 10 bar and the evaporator pressure of 1·5 bar. The evaporator absorbs 75 kJ/min of energy as heat and the vapour is dry saturated at exit from the compressor. Represent the cycle on *T-s* plane and calculate the flow rate of the refrigerant, power consumed and COP of the cycle. Also calculate the COP of the Carnot refrigerator operating between the same temperature limits. The relevant properties of F-12 are given below : 20

Pressure (bar)	Saturation temperature, °C	Enthalpy (kJ/kg)		Entropy (kJ/kg)	
		Liquid	Vapour	Liquid	Vapour
10	41·7	76·8	203·65	-	0·682
1·5	−20·1	17·82	178·84	0·073	0·709

(b) Explain the effect of superheating on the COP of a simple vapour compression cycle. 15

(c) With suitable plant flow diagram and *T-s* diagram, explain the difference between cascade refrigeration system and multistage compression refrigeration system. 15

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