2016-17

MECHANICAL ENGINEERING

SECOND PAPER

Full Marks : 200

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer *any* **ten** questions

1. *(a)* State the first law of thermodynamics and explain the corollaries of the first law. 10

   (b) What are Carnot cycle and Carnot engine? A heat engine, working on Carnot cycle, converts one-fifth of the heat input into work. When the temperature of the sink is reduced by 80 °C, the efficiency gets doubled. Make calculations for the temperature of the source and the sink. 4+6=10

2. *(a)* State, by giving four examples each, the differences between extensive and intensive properties of thermodynamic system. 8

(b) A thermally insulated piston and cylinder arrangement contains 0·25 m^3 of air at 450 kPa and 450 K. During operation without heat exchange with the surroundings, the piston is moved to a position where the pressure is 120 kPa. After this, the air is supplied with heat at constant pressure until the enthalpy is increased by 60 kJ. Calculate—

(i) the net work done during the above processes;

(ii) the index of expansion of a single reversible polytropic process if it has to produce the same work produced in case (i) while working between the same initial and final conditions. 6+6=12

3. (a) Discuss the meanings of mountings and accessories in steam boilers, giving at least three examples of each. 3+3=6

(b) What is the use of Mollier diagram in thermodynamics? Indicate the throttling and isentropic processes in a sketch of Mollier diagram. 4

(c) Steam having 90% dryness and at pressure 10 bar is supplied to an engine at the rate of 0·5 kg s^{-1}, where it expands adiabatically to release pressure 1·5 bar. After that the pressure falls to 0·2 bar at constant volume. Calculate—

(i) dryness fraction after adiabatic expansion;

(ii) specific steam consumption in kg kW^{-1} h^{-1}. 5+5=10

4. (a) Explain briefly the diesel cycle with the help of *P-V* and *T-S* diagrams and derive an expression for the ideal efficiency of a diesel cycle. 12

(b) In a diesel engine, the compression ratio is 13 : 1 and the fuel is cut off at 8% of the stroke. Find the air standard efficiency of the engine. Take γ for air is 1·4. 8

5. (a) What is meant by transient heat transfer? State some of the situations where transient conduction occurs. 5

(b) Write the Fourier rate equation for heat transfer by conduction. Give the units and physical significance of each term appearing in this equation. 5

(c) A hot mild steel sphere (k = 42·5 W/m °C) having 12 mm diameter is planned to be cooled by an air flow at 25 °C. The convective heat transfer coefficient is 114 W/m^2 °C. Determine the following : 10

(i) Time required to cool the sphere from 500 °C to 90 °C

(ii) Total energy transferred from the sphere during the first 2 minutes

6. (a) Draw the *P-V* and *T-S* diagrams for Bell-Coleman cycle refrigeration and deduce the expression for COP in terms of pressure ratio, stating the assumptions, if any. 8

(b) An air refrigeration unit working on Bell-Coleman cycle has a capacity of 10 ton, where the upper pressure limit is 4 bar. The pressure and temperature at the beginning of compression are respectively 1 bar and – 20 °C. The air, after compression, is cooled to 40 °C at constant pressure in the expansion cylinder. Assuming adiabatic expansion and compression, calculate—

(i) COP;

(ii) mass flow rate;

(iii) power needed to drive the plant.

4×3=12

7. (a) For what purpose, condenser is used in the steam turbine plant? 5

(b) How do you calculate condenser efficiency? 3

(c) A steam turbine discharges 90% dry steam at 40 °C to a condenser at the rate of 3000 kg/hr. The estimated air leakage into the condenser is 10 kg/hr. The temperature at the suction of air pump is 30 °C and temperature of condensate is 35 °C. Calculate—

(i) vacuum gauge reading with respect to standard barometer reading of 760 mm Hg;

(ii) capacity of the air pump in m^3/hr. 6+6=12

8. (a) What do you understand by the boundary layer? Illustrate with reference to flow over a flat plate. 5

(b) Flow takes place over a flat plate exposed parallel to free stream. Draw a picture of laminar and turbulent boundary layers and the transition zone separating them. 5

(c) A smooth two-dimensional flat plate is exposed to a wind velocity of 360 km/hr. If laminar boundary layer exists up to a value of $R_{ex} = 2 \times 10^5$, find the maximum distance from the leading edge up to which laminar boundary layer exists and its maximum thickness at the location. Kinematic viscosity of air is $1 \cdot 49 \times 10^{-5}$ m^2/s. 10

9. (a) Discuss what you understand by Morse test in the context of internal combustion engines. 10

(b) During the test on a four-stroke four-cylinder SI engine, it develops a maximum braking torque of 200 Nm at 3000 r.p.m. Taking bore and stroke to be equal, calculate the cylinder dimensions, given brake mean effective pressure at maximum torque as 1000 kPa. 10

10. (a) What do you understand by Newtonian and non-Newtonian fluid? Differentiate between dynamic viscosity and kinematic viscosity. 2+3=5

(b) A hot plate of area 0·25 m^2 is pulled with a uniform velocity 0·5 m/sec with respect to a parallel plate, maintaining

a distance of 0·4 m between them and the space between the plates being filled with a fluid of viscosity 0·001 N-sec/m^2. Calculate the force and power to maintain the motion. 5

(c) What are streamlines in fluid flow? For a two-dimensional steady flow, the fluid density filled is given by $\rho(x, y) = \varepsilon . x . y$, where ε is constant. Deduce the equation for the streamline assuming incompressible flow. 10

11. (a) What are the advantages of burning linear fuel air mixture? 4

(b) What are the effects of supercharging on the following parameters? 6

(i) Power output

(ii) Mechanical efficiency

(iii) Fuel consumption

(c) Describe with neat sketch, the working principle of Wankel combustion engine. 10

12. (a) Define and write the significance of the following : 4+4=8

(i) Mach number

(ii) Reynolds' number

(b) The frictional torque (T) in a compressor depends upon the factors such as impeller diameter (D), rotational speed (N), fluid density (ρ) and viscosity (μ). Using Buckingham's Π-theorem, show that

$$T = \rho N^2 D^5 f\left(\frac{\mu}{\rho N D^2}\right)$$ 12

13. (a) Explain pool boiling. How does it differ from forced convection boiling? 6

(b) Discuss various regimes in boiling and explain the condition for the growth of bubbles. 10

(c) Explain the phenomenon of nucleate boiling. 4

14. (a) Define the terms absorptivity, reflectivity and transmissibility of radiant energy. How are they related to one another? 6

(b) An electric arc furnace emits radiation at a temperature of 2200 K. Assuming it to be a blackbody, determine—

(i) the monochromatic radiant flux density at wavelength 1000 nm;

(ii) the wavelength at which emission is maximum;

(iii) the total emissive power. 4×3=12

(c) What should be the surface area of a heat exchanger if it has to lose heat at the rate of 2 kW by convection alone, given the average surface temperature as 60 °C and ambient temperature as 20 °C? Take convective heat transfer coefficient as 1·15 kW $m^{-2} K^{-1}$. 2

15. (a) Explain the chief characteristics of high pressure boilers. With the help of a neat sketch, briefly explain the working of the Benson boiler. 10

(b) Explain the principle of working of MHD plant. 5

(c) Write a note on flat plate collector for solar energy application. 5

★★★