FS – 22 / 15-16

Mechanical Engineering

Paper – II

Time : 3 hours

Full Marks : 200

The figures in the right-hand margin indicate marks.

*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any **three** of the remaining questions, selecting at least **one** from each Section.*

SECTION – A

1. Attempt any **two** of the following : 20×2 = 40

   (a) What are the forms of energy ? Discuss the concept of availability in non-flow system.

   (b) The atmospheric air at a pressure 1 bar and temperature –5°C is drawn in the cylinder of the compressor of a Bell-Coleman refrigeration machine. It is compressed isentropically to a pressure of 5 bar. In the

cooler, the compressed air is cooled to 15°C, pressure remaining the same. It is then expanded to a pressure of 1 bar in the expansion cylinder, from where it is passed to the cold chamber. Find (i) the work done per kg of air and (ii) the C. O. P. of the plant.

(c) A rod of copper alloy (h = 100 W/m – k) 1.25 cm in diameter spans between two parallel plates 15 cm apart. Air flows over the rod providing heat transfer coefficient of 50 W/m^2 – k at the surface of the rod. The surface temperature of the plates exceeds that of air by 40°C. What is the excess temperature at the centre of the rod over that of air ? Also find out the heat lost from the rod.

2. (a) What are Maxwell relations ? Derive first and second form of entropy equations. 20

(b) In a steam engine, the steam at the beginning of the expansion process is at 7 bar, dryness fraction 0.98 and expansion follows the law,

$pv^{1.1}$ = constant, down to a pressure of 0.34 bar. Calculate per kg of steam (i) work done during expansion and (ii) the heat flow to or from the cylinder walls during the expansion. 20

3. (a) Derive Clapeyron equation for evaporation of liquids. 20

   (b) Two opposed, parallel, infinite planes are maintained at 420 K and 480 K respectivelly. Calculate the net heat flux between these planes, if one has an emissivity of 0.8 and other an emissivity of 0.7. Does it matter which plate has which emissivity ? How this heat flux will be affected if (i) the temperature difference is doubled by raising the temperature 480 K to 540 K and (ii) the planes are assumed to be black. 20

4. (a) With diagrams, explain in detail, various psychrometric processes. 20

   (b) When 0.5 kg of water per minute is passed through a tube of 20 mm diameter, it is found

to be heated from 20°C to 50°C. The heating is accomplished by condensing steam on the surface of the tube and subsequently the surface temperature of the tube is maintained at 85°C. Determine the length of the tube required for fully developed flow. 20

Properties of water at 60°C :

$\rho = 983.2$ kg/m^3, $C_p = 4.178$ kJ/kg-k,

$k = 0.659$ W/m-k, $\upsilon = 0.178 \times 10^{-6}$ m^2/s

SECTION – B

5. Answer any **two** of the following : 20×2 = 40

(a) With the help of P – θ diagram, explain the combustion phenomenon in S. I. engines. What are the factors affecting normal combustion in S. I. engines ?

(b) What are Fanno and Rayleigh lines ? Why do the end states of normal shock lie on those lines ?

(c) (i) Prove that two stream functions ψ_1, ψ_2 can be added up to give yet another stream function ψ.

(ii) Set up an expression for stream function for a uniform flow of 10 m/s parallel to the positive direction of the x-axis.

6. (a) What is dimensional analysis ? What is the difference between Rayleigh's method and Buckingham's π-theorem ? Write the steps to solve a problem using Buckingham's π-theorem. 20

(b) The percentage analysis of gaseous fuel by volume is given as follows :

$CO_2 = 8\%$, $CO = 22\%$, $O_2 = 4\%$, $H_2 = 30\%$ and $N_2 = 36\%$. Determine the minimum volume of air required for complete combustion of 1 m^3 of gas and calculate the percentage composition by volume of the dry products of combustion. If 1.4 m^3 of air is supplied per m^3 of gas, what will be the percentage by volume of CO_2 in the dry products of combustion. 20

7. (a) The energy consumption of a consumer per month is 2,300 kW-hr. The maximum is 12 kW. Using the Hopkinson demand rate as given below, find (i) monthly bill of the consumer and unit energy cost and (ii) lowest possible bill for a month of 30 days and unit energy cost for the given energy consumption. The Hopkinson charges are as follows :

Demand Rates : 0 – 5 kW = Rs. 20 / kW, 6-10 kW = Rs. 15 / kw and 10 –15 kW = Rs. 12 / kW.

Energy Rates : First 100 kW-hr = 20p / kW-hr, next – 500 kW-hr = 15p / kW-hr, next – 2000 kW-hr, 10p / kW-hr, Excess over 2000 kW-hr = 8p / kW-hr. 20

(b) A centrifugal compressor has an impeller tip speed of 360 m/s. Determine (i) the absolute Mach number of flow leaving the radial vanes of the impeller and (ii) the mass flow rate. The following data are given : Impeller tip speed = 360 m/s, radial component of flow velocity at impeller exit = 30 m/s, slip factor = 0.9 flow area at impeller exit = 0.1 M^2, Power input factor = 1.0, isentropic efficiency = 0.9, inlet stagnation temperature = 300 K, inlet stagnation pressure = 100 kN / m^2, R(for air) = 287 J / kg-K, r (for air) = 1.4. 20

8. (a) Discuss : 20

(i) D – Alembert's principle

(ii) Moment of inertia

(b) A uniform flow of 10 m/s is flowing over a doublet of strength 15 m^2/s. The doublet is in the line of the uniform flow. The polar coordinates of a point P in the flow field are 0.9 m and 30^o. Find (i) stream line function and (ii) the resultant velocity at the point. 20