CSM – 55 / 15

Mechanical Engineering

Paper – II

Time : 3 hours

Full Marks : 300

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 ***three*** *of the remaining questions, selecting at least* ***one*** *from each Section.*

SECTION – A

1. Attempt any **three** of the following : 20×3 = 60

   (a) Prove the following relations :

$$\left(\frac{\partial u}{\partial v}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V - P$$

and $$\left(\frac{\partial h}{\partial P}\right)_T = V - T\left(\frac{\partial P}{\partial T}\right)_P$$

   Notation have usual meaning.

(b) Explain with the help of block diagram how a refrigerant produces cooling effect. Discuss, in brief, which refrigerant/s for each of the following applications and why ?

(i) A cold storage of 100 TR capacity using reciprocating compressor.

(ii) A small capacity frozen food cabinet to maintain – 30°C temperature.

(iii) A 800 TR air conditioning plant using centrifugal compressor.

(c) Define and discuss the physical significance of the following :

(i) NTU – Number of transfer Unit

(ii) Lump parameter

(iii) Biol number

(iv) Radiosity

(d) Discuss the main features of a steam boiler. List down atleast 10 factors which should be considered while selecting a boiler.

2. (a) What are the merits and demerits of using

hydrogen as a fuel in an internal combustion engine ? Explain. Suggest some ways by which hydrogen can be used as a fuel in internal combustion engine. 30

(b) (i) Discuss, in brief, the factor affecting comfort air conditioning. What do you mean by term "effective temperature" ? Discuss. 10

(ii) A spray cooling coil is used to operate under the following conditions. Air inlet 28°C DBT / 21°C WBT. Air outlet 10°C DBT / 16° WBT. Total air flow rate 2000 m3/min. Chilled water inlet and outlet temperatures are 7°C and 12°C. Find : 20

(A) Rate of flow of water through the coil

(B) Cooling load on coil.

Properties of moist air from a psychrometric chart are as follows :

DBT ^0C	WBT ^0C	Sp. humidity gm/kg	Sp. volume m^3/kg	Enthalpy KJ/kg
28.0	21.0	12.95	0.87	61.0
10.0	6.0	4.2	0.81	21.0

3. (a) An impeller with an outside diameter of 406 mm and eye radius of 51 mm rotates at 9000 rpm. The inlet and outlet blade angles measured from the radial flow direction are 75° and 83° respectively, while the depth of the blade is 64 mm. 30

Assuming zero slip, zero inlet whirl and hydraulic efficiency of 89%. Calculate the :

(i) Volume flow rate through the impeller

(ii) Stagnation and static pressure rise across the impeller

(iii) Power transferred to the fluid

(b) A cylindrical vessel which has a capacity of 0.3 m^3 contains air at 0.7 bar and $75^{\circ}C$. The vessel is maintained at this temperature as water is injected into it. Calculate the mass of water to be injected so that the vessel is just filled with saturated vapour. If injection now continues untill a total mass of 0.7 kg of water is introduced. Calculate the new total

pressure in the vessel. The vessel is now heated untill all the water in it just evaporates : Calculate. 30

(i) Total pressure for this condition

(ii) The heat to be supplied

At 75°C, the saturation pressure Pg = 0.3855 bar and Vg = 4.133 m^3/kg At Vg = 0.4286 m^3/kg the saturation pressure is 4.35 bar and 4.35 bar the saturation temperature is 419.6 K.

4. (a) Discuss, in detail, the type of power loses which occur in an actual engine as compared to its theoretical air cycle. What do you understand by the term "engine performance" ? Discuss in brief. 30

An engine develops brake power of 19.5 KW and consumes 4.5 litre of petrol during testing 30 minutes. Specific density and calorific value of petrol are 0.78 and 46 MJ/kg respectively. Determine (i) brake thermal efficiency (ii) specific fuel consumption.

(b) In a combustion cycle which is based on dual cycle, the temperature and pressure at the beginning of compression are $90^{\circ}C$ and 1 bar. The heat supplied per kg of air is 1675 KJ/K half of which is supplied at constant volume and half at constant pressure. Calculate the : 30

(i) Maximum power in the cycle

(ii) Percentage of stroke at which cut-off occurs.

Compression ratio is given as 13 : 1, Take γ for compression 1.4.

R = 0.287 KJ/kgK and Cv for product of combustion is $0.71 + 20 \times 10^{-5} T$ where T is in Kelvin.

SECTION – B

5. Answer any **three** of the following : $20 \times 3 = 60$

(a) Briefly explain current scenario of India's thermal power generation. A power station has to supply load as follows :

Time (hours)	Load (MW)
0 – 6	30
6 – 12	90
12 – 14	60
14 – 18	100
18 – 24	50

(i) Draw the load curve and load duration curve.

(ii) Select suitable generating units to supply the load.

(iii) Calculate the load factor, capacity of the plant and plant capacity factor.

(b) Discuss in brief :

(i) Co-efficient of compressibility, k

(ii) Co-efficient of cubical expansion, β

A spherical balloon of 1m diameter contains a gas at 200 KPa and 300 K. The gas inside the balloon is heated untill the pressure reaches 500 KPa. During the process of heating, the pressure is proportional to the diameter of the balloon. Determine the workdone by the gas inside the balloon.

(c) What is the fouling factor ? Why does a "mixed" or "unmixed" fluid arrangement influence heat exchanger performance ? When is the "Log mean temperature difference, LMTD" method most applicable to heat exchanger calculation ?

(d) On a highway a refrigerated truck is speeding at 90 Km/h. The temperature of the surrounding is 55°C. The body of the truck is modelled as a rectangular box with a dimension 11 × 4 × 3 m. considered the boundary layer on the four walls to be turbulent and heat transfer only from four surfaces. The wall surface of the truck is maintained at 10°C. Assume the flow to be parallel to 11 m long side. The thermophysical properties at the mean film temperature of 32.5°C.

$r = 1.165\ kg/m^3$ $C_p = 1.005\ KJ/kg\text{-}K$

$k = 2.67 \times 10^{-2}\ W/m\text{-}k$

$v = 16 \times 10^{-6}\ m^2/s$ $Pr = 0.701$

(i) Calculate the heat loss from the four surfaces.

(ii) Tonnage of refrigeration needed.

(iii) Power required to overcome the resistance acting on four surfaces.

6. (a) What is CANDU type nuclear reactor ? Explain with sketch its main features. Also write a short note on India's nuclear power programme. 20

(b) In a hydroelectric project it was decided to use a number of pelton wheels under the following condition : 40

Total output required 30 MW ; gross head 245 m ; speed 6.25 rev/s. 2 Jets per wheel ; C_v for nozzel 0.97 ; maximum overall efficiency (based on conditions immediately before the nozzles) 81.5% ; dimensionless specific speed not to be exceed 0.22 rev. per jet ; head lost to friction in pipeline is 12 m. Ratio of blade to Jet speed is 0.46.

Calculate the :

(i) Number of wheels required

(ii) Diameters of Jets and wheels

(iii) Hydraulic efficiency, if the blade defects the water Jet through 165° and reduces its relative velocity by 15%

(iv) Percentage of the input power which remains as kinetic energy of the water at discharge.

7. (a) A centrifugal pump 1.3 m in diameter delivers 3.5 m^3/min of water at a tip speed of 10 m/s and a flow velocity 1.6 m/s. The outlet blade angle is 30° to the tangent of impeller periphery. Assuming zero whirl at inlet and zero slip, calculate the torque delivered by the impeller. 20

(b) An air craft is flying at a speed of 1000 Km/h. The pressure and ambient temperature are 0.35 bar and $-15^{\circ}C$ respectively. The turbine, compressor and ram efficiencies are 0.85, 0.8 and 0.85 respectively. The pressure ratio of compressor is 5.0. The heat exchanger effectiveness is 0.8 and pressure drop in heat

exchanger is 0.1 bar. The cabin pressure is 1.06 bar and the air leaves the cabin at 25°C. Assuming simple air craft air conditioning cycle. Find the temperature and pressure at various state points, COP. Mass flow rate, ram work, compressor work, expander work and volume flow rates at turbine and compressor outlets for a 1 TR capacity plant. 40

8. (a) How NO_x is formed in an SI engine ? Discuss in brief. What are the major exhaust emission from an IC engine ? 20

(b) What is the approximate criterion for dividing pure conduction and free in an enclosed space between vertical walls ? Discuss in brief.

Two parallel plates 0.5 × 1.0 m are spaced 0.5 apart. One plate is maintained 1000°C and the other at 500°C. The emissivities of the plates are 0.2 and 0.5 respectively. The plate is located in a very large room, the wall of which are maintained at 27°C. The plate

exchange heat with each other and with the room, but only the plate surface facing each other are to be considered in the analysis. Find the net heat transfer to each plate and to the room. 40