

MECHANICAL ENGINEERING

Paper—II

Time : Three Hours

Full Marks : 300

*Candidates should attempt Question No. 1 from Section-A and Question No. 5 from Section-B which are compulsory, and any **THREE** of the remaining questions, selecting at least **ONE** from each Section. All questions carry equal marks.*

SECTION—A

Answer any **THREE** of the following :— $20 \times 3 = 60$

- (a) State and prove Clausius inequality.
- (b) A 1 m^3 tank containing air at 25°C and 500 kPa is connected through a valve to another tank containing 5 kg of air at 35°C and 200 kPa. Now the valve is opened and the entire system is allowed to reach thermal equilibrium with the surroundings, which are at 20°C . Determine the volume of the second tank and the final equilibrium pressure of air.

(c) Define enthalpy and prove that it is a property of the system.

(d) A gas mixture has the following mass analysis in percentages :

$H_2 = 7.5\%$, $CO = 23.9\%$, $CH_4 = 40.2\%$ and $N_2 = 28.4\%$.

Determine the volumetric analysis. Use a tabular form to illustrate the results and write down the units at the head of each column.

2. (a) A domestic refrigerator is loaded with food and the door closed. During a certain period of time the machine consumes 1 kWh of energy and the internal energy of the system drops by 5000 kJ. Find the net heat transfer for the system. 30

(b) A piston and cylinder arrangement containing a fluid system has a stirring device in the cylinder. The piston is frictionless and it is held down against the fluid due to atmospheric pressure of 101.325 kPa. The stirring device turned 9000 revolutions with an average torque against the fluid of

1.275 mN. Meanwhile the piston of 0.6 m diameter moves out 0.8 m. Find the net work transfer for the system. 30

3. (a) How are the concepts of entropy and unavailable energy related to each other ? Explain the meaning of energy degradation. 30

(b) A household refrigerator is maintained at a temperature of 2°C . Every time door is opened, warm material is placed inside, introducing an average of 420 kJ, but making a small change in temperature of the refrigerator. The door is open 20 times a day and the refrigerator operates at 15% of the ideal COP. The cost of energy is 80 paise per kWh. What is the monthly bill for this refrigerator ? The atmosphere is at 30°C . 30

4. (a) Derive Maxwell relations and explain their importance in thermodynamics. 30

- (b) A turbo-compressor delivers $2.33 \text{ m}^3/\text{s}$ at 0.276 MPa , 43°C which is heated at this pressure to 430°C and finally expanded in a turbine which delivers 1860 kW . During the expansion, there is a heat transfer of 0.09 MJ/s to the surroundings. Calculate the turbine exhaust temperature if changes in kinetic and potential energy are negligible. Assume R (the gas constant) for the working fluid in the turbo-compressor as 0.287 kJ/kg K and $C_p = 1.005 \text{ kJ/kg K}$. 30

SECTION—B

5. Attempt any **THREE** of the following :—

- (a) An engine working on the Otto cycle has a clearance of 17% of stroke volume and initial pressure of 0.95 bar and temperature 30°C . If the pressure at the end of the constant volume heating is 28 bar , calculate :
- the air standard efficiency
 - the maximum temperature in the cycle
 - the ideal mean effective pressure

- (iv) if the relative efficiency of the engine is 50%, calculate the fuel consumption per kWh. LCV of fuel used being 41900 kJ/kg . 20

(b) For a power plant define :

- Load factor
- Utility factor
- Plant operating factor
- Capacity factor
- Demand factor
- Diversity factor. 20

(c) Describe, with schematic diagram, the manufacture of methanol from

- coal or lignite
- municipal solid waste. 20

(d) A group of convergent divergent nozzles expands 6 kg/s of steam from 13 bar dry and saturated, to 1.4 bar at a nozzle efficiency of 0.9. Velocity at the throat is 3% less than theoretical. If the throat section of each nozzle is about 1.28 cm^2 , design the number of nozzles and areas at the throat and exit. 20

6. (a) The dry products of combustion of an air petrol mixture had the volumetric analysis CO_2 12.4%, CO 3.0%, N_2 84.6%. Assuming that the fuel consisted only of carbon and hydrogen and that none was left unburnt, determine :—

- (i) the percentage mass analysis of the petrol,
- (ii) the air petrol ratio by mass. 20

- (b) Compare the performance of the SI engine and CI engine with respect to the following factors :

- (i) power output per unit weight
- (ii) the power output per unit piston displacement
- (iii) acceleration
- (iv) reliability. 20

- (c) Discuss hydrograph and flow duration curve and their use for hydro power plant. 20

7. (a) What is meant by 'delay period' ? It is usually divided into two parts. Name and describe them. What is corresponding term in petrol engine ? 20

- (b) A simple jet carburetor has to supply 5 kg of air per minute. The air is at a pressure of

1.013 bar and at a temperature of 27°C . Calculate the throat diameter of the choke for air fuel velocity of 90 m/s. Take velocity coefficient as 0.8. Assume isentropic and compressible flow. 20

- (c) In a petrol engine discuss the effect of following engine variables on flame propagation :

- (i) Fuel air ratio
- (ii) compression ratio
- (iii) engine load
- (iv) turbulence
- (v) engine speed. 20

8. (a) Distinguish between the working principles of centrifugal, mixed and axial flow compressors. Also derive expressions for pressure rise and aerodynamic forces through a cascade without taking friction into account. 30

- (b) Following data is given of single jet Pelton turbine :
 Generator output = 15 MW, Available head at the nozzle = 750 m, Generator efficiency = 95%, Pelton wheel efficiency = 87%, Velocity coefficient for nozzle = 0.98, mean bucket velocity = $0.47 \times$ jet velocity; outlet angle of bucket = 15° ,

relative velocity of water leaving the buckets =
 $0.90 \times$ that at inlet.

Determine :—

- (i) the diameter of the jet
- (ii) discharge flow rate
- (iii) force exerted by the jet on the buckets.

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