WEST BENGAL UNIVERSITY OF TECHNOLOGY

ME(EE)-411

THERMAL POWER ENGINEERING

Time Allotted: 3 Hours | Full Marks: 70

The questions are of equal value.
The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

GROUP A
(Multiple Choice Type Questions)

1. Answer any *ten* questions. $10 \times 1 = 10$

(i) Natural circulation type of boiler works on the principle of :
(A) differential density of hot and cold water
(B) differential density of hot and cold gases at chimney
(C) natural draught system with chimney
(D) none of these

(ii) The heat rate of a steam power plant cycle is equal to (η_R is cycle efficiency):
(A) η_R (B) $\frac{1}{\eta_R}$ (C) $\frac{1}{\eta_R^2}$ (D) none of these

(iii) An example of fire tube boilers is the :
(A) Cochran boiler (B) Babcock and Wilcox boiler
(C) Stirling boiler (D) Yarrow boiler

(iv) Function of feed check valve is to:
(A) feed required volumetric flow rate of water
(B) maintain water level in the boiler drum
(C) maintain one-way passage for feed water to boiler and stop return of water
(D) none of the above

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(v) Which of the following is a boiler mounting?
(A) economizer (B) preheater (C) superheater (D) fusible plug

(vi) For a Parson's reaction turbine, the degree of reaction is
(A) 80% (B) 50% (C) 75% (D) 20%

(vii) Tangential component of velocity of a steam turbine is called
(A) flow velocity (B) relative velocity (C) whirl velocity (D) absolute velocity

(viii) Maximum efficiency of a Da Laval turbine with nozzle angle α_1 is given by
(A) $\sin^2\alpha_1$ (B) $\cos^2\alpha_1$ (C) $\tan^2\alpha_1$ (D) $\cot^2\alpha_1$

(ix) Spark plug is used in
(A) SI engine (B) CI engine (C) Steam engine (D) None of these

(x) As the mean temperature of heat addition is increased by raising the boiler pressure, the Rankine cycle efficiency:
(A) increases (B) remains practically unchanged
(C) decreases (D) none of the above

(xi) The knocking in spark ignition engine gets reduced
(A) by retarding the spark advance
(B) by increasing the compression ratio
(C) by increasing the cooling water temperature
(D) by increasing the inlet air temperature

(xii) For maximum work output in two stage expansion gas turbine with perfect reheating, the intermediate pressure is
(A) $p_i = \sqrt{p_1 p_2}$ (B) $p_i = \sqrt{p_1 + p_2}$ (C) $p_i = \sqrt{p_1 - p_2}$ (D) $p_i = \sqrt{\frac{p_1 p_2}{2}}$

(xiii) Lancashire boiler is
(A) water tube boiler (B) fire tube boiler
(C) once through boiler (D) super critical boiler

GROUP B
(Short Answer Type Questions)

Answer any *three* questions. $3 \times 5 = 15$

2. (a) What are the basic elements of an ESP? Briefly describe its working principle. 3+2
(b) What is EGR? How does it reduce NO_x emission?

3. (a) How the thermal efficiency/ performance of a simple gas turbine can be improved? 2+3
(b) Explain the Regeneration process.

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4. (a) Write down the merits and demerits of fire tube and water tube boilers. 5
   (b) Write short notes on natural draught and artificial draught.

5. (a) What is Octane and Cetane numbers? 2+3
   (b) Draw neatly Otto cycle, Diesel cycle and dual cycle on T-S plot and compare their efficiencies for a fixed value of compression ratio.

6. (a) What is purpose of turbine governing system? Describe the different types of turbine governing system. 3+2
   (b) Enumerate the various losses in a steam turbine.

7. (a) Distinguish between S.I and C.I. engines. 2+3
   (b) Draw the valve timing diagram of a 4-stroke Diesel engine.

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. $3 \times 15 = 45$

8. (a) Prove that for maximum discharge through the chimney, the height of the hot gas column is equal to the height of the chimney. 5+10
   (b) A forced draught fan supplies air at 10 m/sec against a draught of 20 mm of water across the fuel bed. Estimate the power required to run the fan, if 2500 kg/hr of coal is consumed and 16 kg of air is supplied per kg of coal burned. The temperature of the flue gas and the ambient air may be taken as 600 K and 300 K respectively.
   If the forced draught fan is replaced by an induced draught fan, what will be the power required to drive the fan? Take efficiency of FD fan and ID fan is 80%.

9. (a) The analysis of the coal in a boiler trial was C = 81%, H_2 = 4.5%, O_2 = 8%, remainder incombustible. The Orsat analysis of the dry flue gas was CO_2 = 8.3%, CO = 1.4%, O_2 = 10%, N_2 = 80.3% (by difference). Determine, 7+8
      (i) The weight of air supplied per kg of coal
      (ii) The percentage of excess air
   (b) Following data refer to a boiler plant consisting of an economizer, a boiler and a superheater:
   Mass of water evaporated per hour = 5940 kg, mass of coal burnt per hour = 675 kg, LCV of coal = 31600 kJ/kg, pressure of steam at boiler stop valve = 14 bar, temperature of feed water entering the economizer = 32°C, temperature of feed water leaving the economizer = 115°C, dryness fraction of steam leaving the boiler and entering superheater is 0.96, temperature of steam leaving the superheater = 260°C, specific heat of superheater steam = 2.3 kJ/kg K. Determine (i) Percentage of heat in coal utilized in economizer, boiler and superheater, (ii) Overall efficiency of boiler plant.

Turn Over

10. (a) Explain nozzle efficiency and velocity coefficient. Deduce the relationship between them. 5+10
    (b) An adiabatic steam nozzle is to be designed for a discharge rate of 10 kg/sec of steam from 10 bar and 400°C to a back pressure of 1 bar. The nozzle efficiency is 0.92 and the frictional loss is assumed to take place in the divergent portion of the nozzle only. Assume a critical pressure ratio of 0.5457. Determine the throat and exit areas.

11. (a) Show that for maximum work, the intermediate temperature in the Otto cycle is given by $T_2 = T_4 = \sqrt{T_1 T_3}$, where T_1 and T_3 are initial and maximum temperature respectively in the cycle. Also find out the maximum efficiency of Otto cycle having maximum temperature 1000°C and minimum temperature 15°C. Assume $\gamma = 1.4$. 7+8
    (b) In an air standard diesel cycle, the compression ratio is 16, cut off takes at 5% of the stroke, the compression commences from 1 bar and 28°C. The flow rate is 1 kg/min. Calculate (i) Indicated power, (ii) Air standard efficiency, (iii) Mean effective pressure. Assume C_P = 1.005 kJ/kg K, C_V = 0.718 kJ/kg K.

12. (a) Prove that for a given temperature limit (Max. temperature T_3 and Min. temperature T_1), the expression of maximum net work output $(W_{net})_{max}$ for a closed gas turbine plant is $(W_{net})_{max} = C_p\left(\sqrt{T_3} - \sqrt{T_1}\right)^2$. 7+8
    (b) In a gas turbine the compressor takes in air at a temperature of 15°C and compresses it to four times the initial pressure with an isentropic efficiency of 82%. The air is then passed through a heat exchanger heated by the turbine exhaust before reaching the combustion chamber. In the heat exchanger 78% of the available heat is given to the air. The maximum temperature after constant pressure combustion is 600°C, and the efficiency of the turbine is 70%. Neglecting all losses except those mentioned, and assuming the working fluid throughout the cycle to have the characteristics of air, find the efficiency of the cycle. Assume R = 0.287 kJ/kg K and γ = 1.4 for air and constant specific heats throughout.

13. (a) Show that the maximum efficiency of a 50% reaction turbine is, $\eta = \dfrac{2\cos^2\alpha}{1+\cos^2\alpha}$, where α is the angle at which the steam enters the blade. 7+8
    (b) At a certain point in 50% reaction turbine, the steam leaving a moving row is at 1.5 bar, 0.90 dry. The stream flow rate is 7 kg/s and the turbine speed is 3000 rpm. At entry to the moving blade row, the axial velocity of flow is 0.7 times and at exit from the row 0.75 times the mean blade velocity. The exit angles of both fixed and moving blades are 20°, measured from the plane of rotation, and the height of moving blades at exit is 1/10th of the mean diameter. Determine the height of the moving blades at exit and the power developed in the blade row.