BASIC THERMAL POWER ENGINEERING
(ELEC 2203)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Power consuming device is
(a) steam turbine (b) gas turbine (c) compressor (d) I C Engine.

(ii) Vapour power cycle runs on
(a) Otto cycle (b) Rankine cycle (c) Diesel cycle (d) Brayton cycle.

(iii) $\oint$ of any property is
(a) 0 (b) >0 (c) < 0 (d) >1.

(iv) Keeping the condenser pressure constant, if the boiler pressure is increased, then, the dryness fraction of exhaust steam from turbine
(a) increases (b) decreases
(c) remains the same (d) cannot be concluded.

(v) All natural processes are
(a) reversible (b) irreversible (c) isothermal (d) adiabatic.

(vi) When the relative velocity at inlet and outlet of blade of an impulse turbine is same, then, the passage of steam over blades is
(a) frictionless (b) having considerable friction
(c) turbulent (d) all of these.

(vii) The law which defines entropy is
(a) zeroth law of thermodynamics (b) first law of thermodynamics
(c) Newtons law of viscosity (d) second law of thermodynamics.

(viii) Zeroth law of thermodynamics defines a property called
(a) enthalpy (b) temperature (c) entropy (d) internal energy.

(ix) If $\oint \delta q/T$ is greater than 0, then, the cycle is
(a) impossible (b) reversible (c) irreversible (d) less efficient.

(x) State of steam at 10 bar, 300° C is
(a) wet (b) dry saturated (c) superheated (d) saturated liquid.

Group- B

2. (a) A gas in a piston cylinder assembly undergoes an expansion process for which the relationship between pressure and volume is given by pV^n = Constant. The initial pressure is 3 bar and the initial volume is 0.1 m^3 and the final volume is 0.2 m^3. Determine the work done for the process in kJ if (a) n = 1.5 (b) n = 1.0 and (c) n = 0. [(CO1)(Analyse/IOCQ)]

(b) Steam flows through a turbine at a rate of 2.5 kg/s. The inlet and exit enthalpy of steam are 2700 kJ/kg and 1800 kJ/kg, respectively. Velocity of steam at inlet and outlet are 35 m/s and 250 m/s, respectively. There is heat loss to the surroundings at 40 kW. Calculate the power output from the turbine. [(CO1)(Evaluate/HOCQ)]

6 + 6 = 12

3. (a) Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000 K and 100 K, respectively. Engine A receives 1680 kJ of heat from the high-temperature reservoir and rejects heat to engine B. Engine B takes in heat rejected by engine A and rejects heat to the low-temperature reservoir. If engines A and B have equal thermal efficiencies, determine (i) the heat rejected by engine B (ii) the temperature at which heat is rejected by engine, A (iii) the work done during the process by engines, A and B, respectively. [(CO1)(Analyse/IOCQ)]

(b) A heat pump is used to heat a house in winter and then reversed to cool the house in summer. The interior temperature is to be maintained at 20^0C. Heat transfer through the walls and roof is estimated to be 0.65 kJ/s per degree temperature difference between the inside and outside. What is the minimum power required to drive the heat pump, if the temperature outside in winter is 5^0C? If the same power is used to cool the room to 20^0C in summer, what should be the maximum temperature outside? [(CO1) (Analyse/IOCQ)]

6 + 6 = 12

Group - C

4. (a) Two kgs of a certain gas with Cp = 0.85 kJ/kg K and Cv = 0.70 kJ/kg-K is allowed to expand adiabatically through a partly open valve, whereby its volume changes from 0.0113 m^3 to some higher volume and during the process the entropy increases by 0.8 kJ/K. Find the volume after expansion of gas. [(CO1)(Evaluate/HOCQ)]

(b) One kg of ice at -20°C is exposed to the atmosphere which is at 20°C. The ice melts and comes into thermal equilibrium with the atmosphere. Calculate the entropy increase of the universe. Take Cp of ice as 2.093 kJ/kg K and latent heat of the fusion of ice as 334.5 kJ/kg. [(CO1)(Evaluate/HOCQ)]

6 + 6 = 12

5. A regenerative cycle operates with steam supplied at 30 bar and 300°C, and condenser pressure of 0.08 bar. The extraction points for two heaters (one closed and one open) are at 3.5 bar and 0.7 bar, respectively. Calculate the thermal efficiency of the plant, neglecting pump work. [(CO3)(Evaluate/HOCQ)]

12

Group - D

6. (a) Dry saturated steam at 26 bar expands isentropically in a convergent-divergent nozzle to 12 bar. Determine the mass flow rate per cm^2 of throat area and the steam quality at the nozzle exit if the expansion is assumed to be in equilibrium for (i) n = 1.135 (ii) n = 1.3 [(CO5)(Analyse/IOCQ)]

(b) A stage of an impulse steam turbine operates close to the maximum blading efficiency. The blades are equiangular, and the friction effects in blades may be neglected. The mean blade velocity is 200 m/s and the steam flow rate is 0.75 kg/s. Find the discharge angle at which the steam leaves the blades and the diagram power. [(CO5)(Analyze/IOCQ)]

6 + 6 = 12

7. (a) Show that the maximum discharge of steam through the nozzle takes place when the ratio of steam pressure at the throat to the inlet pressure is given by,

$$\frac{p_2}{p_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n+1}}$$ [(CO5)(Understand/LOCQ)]

(b) A turbine rotor has the mean diameter of 250 mm and the blade angles are equal. The nozzle angle is 20°, the steam speed at nozzle outlet is 930 m/s and the blade friction factor is 0.85. Find the best angle of the blades, the turbine speed in rpm, the steam consumption to generate 10 kW, and the blade efficiency. [(CO5)(Analyze/IOCQ)]

6 + 6 = 12

Group - E

8. The following data were obtained in a boiler trial:
mass and temperature of feed water = 680 kg/hr and 20°C
steam pressure and its temperature = 15 bar and 300°C
coal used and its calorific value = 98 kg/hr and 26500 kJ/kg
flue gas formed and its temperature at chimney = 18 kg/kg of coal supplied and 300°C
Ash and unburnt coal is ash-pit = 4 kg/hr with 2200 kJ/kg calorific value
Mean specific heat of flue gases and feed water = 1 kJ/kg K and 4.187 kJ/kg K, respectively
If the ambient temperature in the boiler room is 28°C,
determine,
(i) boiler efficiency
(ii) equivalent evaporation from and at 100°C
(iii) total heat loss. [(CO6)(Evaluate/HOCQ)]

12

9. (a) The following observations were recorded during the test of a surface condenser:
Vacuum in condenser : 710 mm of Hg. Barometer reading: 760 mm of Hg. Temperature in condenser : 35°C
Hot well temperature : 31°C Cooling water circulated : 800 kg/min
Inlet Cooling water Temperature : 13°C Outlet cooling water Temperature : 29°C
Condensate rate : 25 kg/min
Find (i) the mass of air in kg per m^3 of condensate volume.
(ii) the dryness fraction of steam entering the condenser.
(iii) the vacuum efficiency. [(CO6)(Evaluate/HOCQ)]

(b) Describe very briefly how ash is handled in a thermal power plant.
[(CO6)(Understand/LOCQ)]
6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	12.5	37.5	50

Course Outcome (CO):

After the completion of the course students will be able to

CO1: Analyze a thermodynamic system and calculate work transfer in various quasistatic processes, Understand the difference and correlation between heat transfer and work transfer.

CO 2: Read and interpret the values of properties of water/steam from steam table and Mollier chart for evaluation of heat transfer and work transfer in processes involving

CO 3: Understand the basics of thermal power generation and calculate the efficiencies of Rankine cycles with reheat and regeneration.

CO 4: Understand various types of boilers used in thermal power plants and draw up a heat balance sheet and design the chimney height based on various conditions.

CO5: Calculate power output, blading efficiency, staging efficiency from Impulse and Reaction turbines and appreciate the importance of compounding and governing of turbines.

CO6: Calculate the water requirement for power plant, power required to drive fans, condenser efficiency.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.