BASIC THERMAL POWER ENGINEERING
(ELEC 2203)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

USE STEAM TABLE / MOLLIER DIAGRAM WHEREVER NECESSARY.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Mollier diagram is a plot of
(a) Temperature and entropy (b) Enthalpy and entropy
(c) Pressure and entropy (d) Pressure and volume

(ii) A heat pump working on reversed Carnot cycle has a C.O.P of 5. If it is works as a refrigerator taking 1kW of work input, the refrigeration effect will be
(a) 1kW (b) 3kW (c) 5kW (d) 4kW

(iii) Which law of thermodynamics is the basis for the concept of temperature?
(a) Zeroth Law (b) First Law (c) Second Law (d) Third Law.

(iv) The condition for maximum blading efficiency in turbines occurs when the blades
(a) move at supersonic speeds (b) are very short
(c) operate at low pressure ratios (d) have a specific profile angle

(v) Natural circulation in a boiler is driven by
(a) fans (b) pumps
(c) density differences (d) temperature differences

(vi) Rankine cycle comprises of
(a) two isentropic processes and two constant volume processes
(b) two isentropic processes and two constant pressure processes
(c) two isothermal processes and two constant pressure processes
(d) two isothermal processes and two constant volume processes.

(vii) A single-stage impulse turbine is also known as
(a) Curtis stage turbine (b) Reaction turbine
(c) Da Laval Turbine (d) Rateau Turbine

(viii) Vacuum efficiency of a condenser is a measure of its ability to:
(a) increase steam pressure
(b) decrease steam temperature
(c) maintain low pressure inside the condenser
(d) improve condensate quality.

(ix) The component of a boiler that increases the temperature of saturated steam to its dryness fraction is called _____.
(a) evaporator (b) superheater
(c) economizer (d) condenser

(x) 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

Fill in the blanks with the correct word

(xi) An adiabatic process is one in which _____ is transferred to or from the system.

(xii) The First Law of Thermodynamics is a statement of the conservation of _____.

(xiii) Blading efficiency in turbines is a measure of how well the blades extract _____ from the fluid.

(xiv) The _____ law of thermodynamics puts a limit on the conversion of a given amount of heat into work.

(xv) The latent heat of vaporisation is _____ at the critical point.

Group - B

2. (a) A gas initially at a pressure of 510 kPa and a volume of 142 litres undergoes a process and has a final pressure of 170 kPa and a volume of 275 litres. During the process, the enthalpy decreases by 65 kJ. Take C_v = 0.718 kJ/kg-K. Determine (i) change in internal energy, (ii) specific heat at constant pressure, and (iii) specific gas constant. *[(CO1)(Evaluate/HOCQ)]*

(b) 1 kg of gas occupying 0.15 m^3 at a pressure of 12 bar is heated at constant pressure until volume is 0.28m^3. The gas is then expanded adiabatically until its volume is 1.5 m^3. Calculate (i) temperature at the end of constant-pressure heating and at the end of adiabatic expansion. (ii) total work done Take Cp= 1.068 kJ/kg-K and C_v=0.775 kJ/kg-K. *[(CO1)(Evaluate/HOCQ)]*

6 + 6 = 12

3. (a) A hydraulic turbine is supplied with 25 m^3/s of water. At the turbine inlet, the water is at 5 bar, and 25°C with an elevation above datum of 100 metres and a flow velocity of 1 m/s. At the turbine exit, the water is at 1.2 bar and 25° C with zero elevation and a flow velocity of 11 m/s. The turbine loses 5 J of heat per kg of water flowing through it. Assuming that the water is an incompressible fluid

with specific heat of 4.178 kJ/kg-K, determine,(i) the change in potential energy, (ii) the change in internal energy, and (iii) the power output in MW.

[(CO1)(Evaluate/HOCQ)]

(b) A reversible heat engine operates in two environments. In the first operation, it draws 12000 kW from a source at 400°C and in the second operation, it draws 25000 kW from a source at 100°C. In both operations, the engine rejects heat to a thermal sink at 20°C. Determine the operation in which the engine delivers more power. *[(CO1)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - C

4. (a) What is pure substance ? What is triple point? Give pressure and temperature of water at its triple point? Draw the phase equilibrium diagram for a pure substance on p-T coordinate and shows the triple point. *[(CO2)(Apply/IOCQ)]*

(b) Steam initially at 1.5 MPa, 350^0C expands reversibly and adiabatically in a steam turbine to 40^0C. Determine the ideal work output of the turbine per kg of steam. Draw the T-s and h-s diagram of the process. *[(CO2)(Apply/IOCQ)]*

(1 + 1 + 1 + 3) + 6 = 12

5. In a single –heater regenerative cycle the steam enters the turbine at 30 bar 400^0C and the exhaust pressure is 0.1 bar. The feed water heater is a direct contact type which operates at 4.5 bar. Find (i) the efficiency and the steam rate of the cycle and (ii) the increase in mean temperature of heat addition, efficiency and steam rate, as compared to the Rankine cycle (without regeneration). Neglect Pump work. *[(CO3)(Evaluate/HOCQ)]*

12

Group - D

6. (a) The angle at inlet and discharge of the blading of a 50% reaction turbine are 35^0 and 20^0, respectively. The speed of rotation is 1500 rpm and at a particular stage, the mean ring diameter is 0.67 m and the steam condition is at 1.5 bar, 0.96 dry. Estimate (i) the required height of blading to pass 3.6 kg/s of steam, and (ii) the power developed by the ring. *[(CO5)(Analyse/HOCQ)]*

(b) Illustrate the concept of supersaturated or metastable flow of steam through a nozzle with an appropriate *h-s* diagram, and discuss the significance of the Wilson line in this phenomenon. *[(CO5)(Remember/LOCQ)]*

7 + 5 = 12

7. (a) The velocity of steam at inlet to a single row impulse turbine is 400 m/s and the nozzle angle is 20^0. The mean blade speed is 150 m/s and the axial thrust one the blade is estimated to be zero. Make the calculation: (i) inlet and outlet angle of moving blades (ii) power developed for steam flow rate of 1.5 kg/s and (iii) magnitude the direction of velocity of steam at exit. Neglect friction effect.

[(CO5)(Analyse/HOCQ)]

(b) Describe briefly the important methods used for the governing of steam turbine.

[(CO5)(Remember/LOCQ)]

8 + 4 = 12

Group - E

8. (a) A boiler is equipped with a chimney of 30 m height. The ambient temperature is 25°C. The temperature of flue gases passing through the chimney is 300°C. If the air flow is 20 kg/kg of fuel burnt, find (i) draught produced (ii) the velocity of flue gases passing through chimney if 50% of the theoretical draught is lost in friction. *[(CO4)(Evaluate/HOCQ)]*

   (b) During a trial on a condenser, the following readings were recorded:
   Barometer reading = 766 mm of Hg
   Actual vacuum recorded by gauge = 716 mm of Hg
   Temperature of exhaust steam =35°C
   Temperature of hot well = 29°C
   Inlet temperature of cooling water = 15°C
   Outlet temperature of cooling water =24°C .
   Calculate (i) corrected vacuum to standard barometer reading of 760 mm of mercury,(ii) vacuum efficiency, (iii) undercooling of condensate, and (iv) condenser efficiency. *[(CO6)(Analyse/IOCQ)]*

6 + 6 = 12

9. (a) A steam generator evaporates 18000 kg/h of steam at 12.5 bar and a quality of 0.97 dry from feed water at 105°C, when coal is fired at 2040 kg/h. If the higher calorific value of coal is 27400 kJ/kg, find the (i) heat rate of the boiler in kJ/h, (ii) equivalent evaporation, and (iii) thermal efficiency. *[(CO4)(Evaluate/HOCQ)]*

   (b) What are the differences between boiler mountings and boiler accessories? Name two boiler mountings and two boiler accessories and their functions. *[(CO4)(Remember/LOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	15.62	18.75	65.63

Course Outcome (CO):

After the completion of the course students will be able to

CO 1 : 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 steam

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.

CO 5 : Calculate power output , blading efficiency , staging efficiency from Impulse and Reaction turbines and appreciate the importance of compounding and governing of turbines.

CO 6 : 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.*