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) PMM 1 is impossible because it violates.
(a) Zeroth law (b) 1st law of thermodynamics
(c) calorimetric principle (d) 2nd law of thermodynamics.

(ii) In case of Parson's reaction turbine, enthalpy drop happens
(a) both in fixed and moving blades (b) only in fixed blades
(c) only in moving blades (d) only in nozzles

(iii) The following devices are the main devices in coal based thermal power plant except.
(a) steam turbine (b) Feed Water Pump
(c) Boiler (d) compressor

(iv) Two engines A and B are connected to the same heat source and sink drawing same amount of heat. Engine A is reversible but engine B is not. Then,
(a) engine B produces more work (b) engine A produces more work
(c) engine A is more efficient (d) both (b) & (c)

(v) In an ideal Rankine cycle, if the degree of superheat is increased at the same pressure, then,
(a) turbine work increases
(b) heat input to boiler increases
(c) exhaust steam from turbine becomes more dry
(d) all of these.

(vi) Pulverisation of coal is done to
(a) increase surface area (b) facilitate rapid burning
(c) decrease amount of unburnt coal (d) all of these

(vii) Followings are the shaft power producing devices except
(a) SI engine (b) CI engine
(c) cooling tower (d) steam turbine

(viii) A regenerative feed water heating in a vapour power cycle with infinite number of feed water heaters has an efficiency equal to
(a) Otto cycle (b) Carnot cycle (c) Diesel cycle (d) Brayton cycle

(ix) The pump work required per kg to send feedwater from condenser pressure of 0.5 bar at saturated liquid condition to boiler pressure of 120 bar is approximately
(a) 12.3 kJ/kg (b) 0.123 kJ/kg (c) 123 kJ/kg (d) none of these

(x) Ideal working fluid for vapour power cycle should have
(a) high critical temperature
(b) saturation pressure at the temperature of heat rejection should be above atmospheric pressure
(c) specific heat of liquid should be low
(d) all of these.

Group- B

2. (a) At the beginning of compression stroke of a two cylinder 4-stroke internal combustion engine, the air is at a pressure of 101.325 kPa. Compression reduces the volume to 1/5th of its original volume. The law of compression follows the path $pv^{1.4}$ =constant. If the bore and stroke of each cylinder is 0.15 m and 0.25 m respectively, determine the power absorbed in kW by compression strokes when the engine speed is 1000 rpm. [(CO1)(Evaluate/HOCQ)]

(b) Two streams of air one at 1 bar, 27^0C and velocity of 30m/s and the other at 5 bar, 227^0C and 50 m/s velocity , mix with each other in equal proportion in a chamber from which heat is removed @ 100 kJ/kg . The mixture is then passed through an adiabatic nozzle. Find the velocity of the stream issuing out of the nozzle. The temperature of air stream leaving the nozzle is 27^0C and its cp is 1.005 kJ/kgK. [(CO1)(Evaluate/HOCQ)]

6 + 6 = 12

3. (a) A reversible heat engine operates between 875 K and 310 K and drives a reversible refrigerator operating between 310 K and 250 K. The engine receives 2000 kJ of heat and net work output from the arrangement equals 350 kJ. Calculate the cooling effect of the refrigerator. [(CO1) (Evaluate/LOCQ)]

(b) Three Heat engines HE1, HE2 and HE3 operate between temperatures 1000K and 300 K. Ratio of the work produced by them are 4:3:2. What are the intermediate temperatures of this arrangement? [(CO1) (Evaluate/IOCQ)]

6 + 6 = 12

Group – C

4. (a) One kg of ice at -20^0 C is exposed to the atmosphere at 35^0C. The ice melts and comes in thermal equilibrium with the atmosphere. Calculate the entropy increase of the universe. Take Cp ice as 2.093 kJ/kg K and latent heat of ice as 334.5 kJ/kg. [(CO2)(Evaluate/HOCQ)]

(b) A vessel of volume 0.04 m^3 contains a mixture of saturated water and saturated steam at 250^0C. The mass of the liquid present is 10 kg. Find the pressure, the mass, the specific volume, the enthalpy, the entropy and the quality of mixture.
[(CO2)(Analyze/IOCQ)]

6 + 6 = 12

5. A power plant operates on reheat regenerative vapour power cycle with a feed water heater and generates 120 MW. The steam enters the hp turbine at 150 bar, 600^0C, and expands to 20 bar. Then the steam is reheated to 600^0C at the same pressure. The Steam for the feed water heater is extracted from the lp turbine at the pressure of 5 bar and the remaining steam is expanded to condenser pressure of 0.1 bar. Assuming ideal processes, determine
(i) mass flow rate of steam in kg/h (ii) fraction of steam bled for feed water heating (iii) thermal efficiency of the cycle. [(CO3)(Evaluate/HOCQ)]

12

Group - D

6. (a) Steam enters a convergent-divergent nozzle at 15 bar, 300^0C and leaves at 2 bar. The inlet velocity to the nozzle is 150 m/s. Find the required throat and exit area for steam flow rate of 1 kg/s. Take C_{ps}=2.4 kJ /kg-K and nozzle efficiency is 90%.
[(CO5)(Evaluate/LOCQ)]

(b) The nozzles of a De-Laval turbine deliver 1.5 kg/s of steam at a speed of 800m/s to a ring of moving blades having a speed of 200 m/s. The nozzle angle is 18^0 and the exit angle of the moving blades is 25^0. The blade velocity co-efficient is 0.75. Calculate
(i) the diagram efficiency
(ii) the power developed
(iii) the axial thrust on the turbine rotor. [(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

7. (a) A 50% reaction turbine is supplied with steam at 60 bar, 600^0 C . The condenser pressure is 0.07 bar. If the reheat factor is assumed to be 1.04 and the stage efficiency is constant throughout at 80%, Calculate the steam flow required for a diagram power of 25 MW. [(CO5)(Evaluate/HOCQ)]

(b) The velocity of steam exiting the nozzle of a turbine is 400m/s. The blades operate close to the maximum blading efficiency. The nozzle angle is 20^0. Considering equiangular blades and assuming a friction factor of 0.7, calculate (i) power developed and (ii) blading efficiency. [(CO5)(Evaluate/HOCQ)]

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 = 18 kg/kg of coal supplied
Flue gas temperature at chimney = 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 = 1.025 kJ/kg K and 4.18 kJ/kg K
Moisture of fuel : 2 % by mass
If the ambient temperature in the boiler room is 28°C, determine the
(i) boiler efficiency
(ii) equivalent evaporation from and at 100°C.
Also draw up a heat balance sheet. [(CO4)(Evaluate/HOCQ)]
12

9. (a) A thermal power station works on natural draught. The height of the chimney is 40m. The ambient temperature is 35^0C and the temperature of the flue gases passing through the chimney at its base is 300^0C.The air-fuel ratio is 17:1. Calculate the diameter of the chimney at its base, if the head loss is 25% of the ideal draught. [(CO4)(Analyse/IOCQ)]

(b) Calculate the equivalent evaporation from and at 100^0C for a boiler, which receives water at 60^0C and produces steam at 1.5 MPa and 300^0C. The steam generation rate is 16000 kg/h. Coal is burnt at the rate of 1800 kg/h. The calorific value of coal is 34750 kJ/kg. Also calculate the thermal efficiency of the boiler. [(CO2)(Evaluate/LOCQ)]
6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	18.75	62.5

Course Outcome (CO):

After going through the course, the 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
- CO2• 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
- CO3• Understand the basics of thermal power generation and calculate the efficiencies of Rankine cycles with reheat and regeneration
- CO4• 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