POWER PLANT ENGINEERING
(MECH 4242)

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) The steam is compressed isentropically in a pump from saturated liquid at 0.08 bar to 100 bar. The pump work in kJ per kg of saturated water is approximately
(a) 10 (b) 0.1 (c) 100 (d) none of these.

(ii) Ultimate analysis of fuel aims at determining
(a) HCV (b) LCV
(c) % of C, H, N, S and moisture (d) ignition point.

(iii) If V_{r1} and V_{r2} are the relative velocities of the steam at entry and exit of the blade of a reaction turbine then
(a) $V_{r1} \geq V_{r2}$ (b) $V_{r1} \leq V_{r2}$ (c) $V_{r2} > V_{r1}$ (d) none of these.

(iv) The maximum temperature that can be used in a vapour power cycle is constrained by a limit called
(a) tolerance limit (b) metallurgical limit
(c) elastic limit (d) critical limit.

(v) Maximum power developed per kg of steam by a single stage impulse turbine having U as blade velocity under symmetrical blading and no friction condition is
(a) U^2 (b) $2U^2$ (c) 2U (d) U^4.

(vi) The steam is expanded isentropically from 40 bar, 500°C in a turbine to 5 bar from where it is reheated to 400°C. The quality of exhaust steam from turbine at 5 bar is
(a) saturated liquid (b) saturated vapour
(c) wet steam (d) superheated steam.

(vii) A plant has a peak load of 1000 MW but the average annual load is 350 MW. The annual load factor of the plant is
(a) 0.35 (b) 28.5 (c) 35 (d) 3.5.

(viii) The following is not a part of hydro-electric power plant
(a) catchment area (b) spillways
(c) conduits (d) BWR.

(ix) In a Parson's reaction turbine, the enthalpy drop in fixed blade is 20 kJ/kg. Enthalpy drop in moving blade in kJ/kg is
(a) 40 (b) 10 (c) 20 (d) 30.

(x) In a binary Mercury-vapour cycle, Hg cycle operates at 50% efficiency and steam cycle operates at 40%. The combined cycle efficiency will be
(a) 45% (b) 80% (c) 35% (d) 70%.

Group- B

2. (a) A power plant works on Rankine cycle with superheat and reheat. The steam enters the first stage turbine at 8.0 MPa, 480°C and expands to 0.7 MPa. It is then reheated to 440°C before entering the second stage turbine, where it expands to the condenser pressure of 0.008 MPa. The net power output of the cycle is 100 MW. Determine
(i) thermal efficiency of the cycle
(ii) mass flow rate of steam in kg/h
(iii) specific steam consumption in kg/kWh
(iv) the rate of heat transfer from the condensing steam as it passes through the condenser in MW. [(CO1)(Evaluate/HOCQ)]

(b) In a power plant, the efficiencies of the electric generator, turbine (mechanical), boiler, cycle, and the overall plant are 0.96, 0.94, 0.91, 0.41 and 0.32 respectively. What percentage of the total electricity generated is consumed in running the auxiliaries? [(CO1)(Analyse/IOCQ)]

9 + 3 = 12

3. A binary vapour cycle operates on mercury and steam, saturated mercury vapour at 4.5 bar is supplied to the mercury turbine, from which it exhausts to 0.04 bar. The mercury condenser generates saturated steam at 15 bar which is expanded in a steam turbine to 0.04 bar.

Find (i) the overall efficiency of the cycle.
(ii) If 50,000 kg/h of steam flows through the steam turbine, what is the flow through the mercury turbine?
(iii) Assuming that all the processes are reversible, what is the useful work done in the binary vapour cycle for the specified steam flow?
(iv) If the steam leaving the mercury condenser is superheated to 300°C in a super heater in a mercury boiler and if the internal efficiencies of the mercury and steam turbines are 0.85 and 0.90 respectively, calculate the overall efficiency of the cycle.

The properties of saturated mercury are given below:

P(bar)	t(^{0}C)	h_f	h_g	s_f	s_g	v_f	v_g
		(kJ/kg)	(kJ/kg)	(kJ/kgK)	(kJ/kgK)	(m^3/kg)	(m^3/kg)
4.5	450	62.93	355.98	0.1352	0.5397	79.9×10^{-6}	0.068

0.04	216.9	29.98	329.85	0.0808	0.6925	$76.5x10^{-6}$	5.178

[(CO1)(Evaluate/HOCQ)]
12

Group - C

4. The following data were recorded in a steam power plant consisting of a boiler , an economiser, and a super heater.
Steam pressure = 15 bar
Mass of steam generated = 5800 kg/h
Mass of coal used = 690 kg/h
Calorific value of coal = 31500 kJ/kg of coal
Temperature of feed water entering the economiser = 28°C
Temperature of feed water leaving the economiser = 135°C
Dryness fraction of steam the boiler is 0.90
Temperature of feed water leaving the economiser = 350°C
Determine (i) the overall efficiency of the plant. (ii) the percentage of heat utilized in economiser, boiler and super heater. [(CO2)(Evaluate/HOCQ)]
12

5. (a) A sample of coal contains 78% carbon, 6% hydrogen, 1.2% nitrogen, 7.8% oxygen and 7% incombustible substance. Find the minimum quantity of air required for complete combustion of 1 kg of coal. [(CO4)(Evaluate/HOCQ)]
(b) A chimney of height 28 m is filled with hot gases at a temperature of 300°C. The temperature of outside air is 35°C. If the available draught is 85 % of the theoretical draught, calculate the available draught in terms of water head. The boiler is supplied with 15 kg of air per kg of fuel burnt, also find out the velocity of the gases passing out through the chimney. [(CO2)(Evaluate/HOCQ)]
6 + 6 = 12

Group - D

6. (a) In a stage of an impulse turbine, provided with single row wheel, the mean diameter of the blade ring is 800 mm and the speed of rotation is 3000 rpm. The steam ejects from the nozzles with a velocity of 300 m/s and the nozzle angle is 20°. The rotor blades are equiangular and the blade friction factor is 0.85. What is the power developed in the blading when the axial thrust on the blades is 140 N. [(CO3)(Evaluate/HOCQ)]
(b) 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 1kg/s. Take C_{ps}=2.4 kJ /kg-K and nozzle efficiency is 90%. [(CO3)(Analysis/IOCQ)]
6 + 6 = 12

7. (a) The first stage of a turbine is a two-row velocity-compounded impulse wheel. The steam velocity at inlet is 600 m/s, the mean blade velocity is 120 m/s, and the

blade velocity co-efficient for all blades is 0.9. The nozzle angle is 16° and the exit angles for the first row of moving blades, the fixed blades, and the second row of moving blades are 18°, 21° and 35° respectively.
Calculate :

(i) the blade inlet angles for each row ;
(ii) the driving force for each row of moving blades and the axial thrust on the wheel, for a mass flow rate of 1 kg/s;
(iii) the diagram power per kilogram per second steam flow, and the diagram efficiency for the wheel;
(iv) the maximum possible diagram efficiency for the given steam inlet velocity and the nozzle angle. [(CO3)(Evaluate/HOCQ)]

(b) Prove that for a single stage impulse turbine the maximum blading efficiency will occur when the speed ratio is $\frac{\cos \alpha 1}{2}$, where α_1 is the nozzle angle. [(CO3)(Remember/LOCQ)]

8 + 4 = 12

Group - E

8. (a) A power station supplies the following loads to the consumers:

Time in Hours	0-6	6-10	10-12	12-16	16-20	20-22	22-24
Load (MW)	30	70	90	60	100	80	60

(i) Draw the load curve and estimate the load factor of the plant.
(ii) What is the load factor of a standby equipment of 30 MW capacity if it takes up all loads above 70 MW?
(iii) Also find out the use factor of the stand by unit. [(CO1)(Analyse/LOCQ)]

(b) Write short notes on:
(i) Catchment Area
(ii) Reservoir
(iii) Dam
(iv) Spillways. [(CO6)(Remember/LOCQ)]

6 + 6 = 12

9. (a) The following observations were taken during a test on a surface condenser: Vacuum in condenser = 710 mm of Hg, Barometer reading = 760 mm of Hg, Temperature in condenser = 31°C, Hot-well temperature = 29°C, Cooling water circulated = 800 kg/min, Inlet and outlet temperatures of cooling water = 13°C and 27°C respectively. Condensate = 25 kg/min.
Find
(i) the mass of air in kg per m^3 of condensate volume
(ii) the dryness fraction or quality of steam entering the condenser
(iii) the vacuum efficiency. [(CO5)(Evaluate/HOCQ)]

(b) With the help of a neat diagram explain the functioning of a Pressurized Water Reactor in a Nuclear Power Plant. [(CO6)(Remember/LOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	22.92	9.38	67.70

Course Outcome (CO):

Course Outcomes: After completion of the course, the students will be able to:-

CO1 Evaluate and Select different types of Power plants based on availability of fuels.
CO2 Design and Compare between Natural draft and Artificial draft Chimneys.
CO3 Differentiate and Evaluate the impulse and reaction turbine and nozzle performance.
CO4 Analyze the combustion process of coal in boiler and Calculate air requirement.
CO5 Design surface condensers and cooling towers and calculate the water flow requirement.
CO6 Compare the working principle of nuclear and hydel power plant.

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