POWER PLANT ENGINEERING
(MECH 4101)

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 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.

(ii) In the regenerative cycle feed water is heated by
(a)exhaust gases (b) heaters
(c) draining steam from the turbine (d) all of the above.

(iii) Steam is coming out of a nozzle at a velocity of 800 m/s with nozzle angle 18° of an impulse turbine with blade velocity of 380 m/s and producing 433.2 KW power for a mass flow rate of 1.5 kg/s. Which of the following statement/s is/ are true
(a) exit velocity of steam is axial
(b) it is producing maximum power
(c) both (a) and (b)
(d) neither (a) nor (b).

(iv) Evaporative condensers have
(a) steam in pipes surrounded by water
(b) water in pipes surrounded by steam
(c) both (a) & (b)
(d) none of these.

(v) The stage efficiency(η_S) of a steam turbine is given by
(a)η_B/η_N (b) η_N/η_B (c)$\eta_B \times \eta_N$ (d) none of these.
[η_B: $blading\ efficiency$; η_N: $nozzle\ efficiency$]

(vi) In the Orsat apparatus, the KOH solution is used to absorb
(a) CO_2 (b) O_2 (c) N_2 (d) CO.

(vii) The steam is expanded isentropically from 80 bar, 500°C in a turbine to 33 bar from where it is reheated to 500°C. The temperature of the exhaust steam from turbine at 33 bar is approximately
(a) 240°C (b) 360°C (c) 500°C (d) 400°C.

(viii) 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.

(ix) Utilization factor associated with a power plant can be expressed as
(a) $\frac{load\ factor}{capacity\ factor}$ (b) $\frac{capacity\ factor}{load\ factor}$
(c) $load\ factor \times capacity\ factor$ (d) none of these.

(x) Moderator in nuclear plants is used to
(a) reduce temperature
(b) extract heat from nuclear reaction
(c) control the reaction
(d) cause collision with the fast moving neutrons to reduce their speed.

Group – B

2. (a) The net power output of an ideal reheat regenerative steam cycle is 80 MW. Steam enters the high pressure turbine at 80 bar, 500°C and expands till it becomes saturated vapour. Fraction of steam goes into an open feed water heater and the balance steam is reheated to 400°C, after which it is expanded in a low pressure turbine to 0.07 bar. Find (i) the reheat pressure (ii) the steam flow rate to the hp turbine (iii) the cycle efficiency (iv) the diameter of the connecting pipe between the turbine and the condenser if the maximum flow velocity is restricted to 130m/s.

(b) Define steam rate and heat rate of a steam power plant.

10 + 2 = 12

3. A mercury cycle is superposed on the steam cycle operating between the boiler outlet condition at 40 bar, 400°C and the condenser temperature of 40°C. The heat released by mercury condensing at 0.2 bar is used to impart the latent heat of vapourization to the water in the steam cycle. Mercury enters the mercury turbine as saturated vapour at 10 bar. Compute (i) kg of

mercury circulated per kg of steam. (ii) the efficiency of the combined cycle.The properties of mercury values are given below:

p (bar)	t (°C)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg-K)	s_g (kJ/kg-K)	v_f (m³/kg)	v_g (m³/kg)
10	515.5	72.23	363.0	0.1478	0.5167	80.9×10^{-6}	0.0333
0.2	277.3	38.35	336.55	0.0967	0.6387	77.4×10^{-6}	1.163

12

Group – C

4. Draw up a heat balance sheet, and calculate the boiler efficiency and equivalent evaporation given the following data of a boiler trial:
Feed water supplied : 680 kg/h
Temperature of feed water : 30°C
Steam generated at pressure : 15 bar
Steam Temperature : 300°C
Fuel used : 95 kg/h
Calorific value of fuel : 26500 kJ/kg
Ash and unburnt coal in ashpit : 4kg/h with a calorific value 3000 kJ/kg
Mass of dry flue gases : 15 kg/ kg of fuel burnt.
Temperature of the gases : 300°C
Boiler House temperature : 35°C
Moisture in fuel : 2% by mass.
Mean specific heat of flue gases : 1.025 kJ/kg-K

12

5. (a) A steam generator delivers steam at 100 bar, 500°C. The feed water inlet temperature is 160°C ($h = 677\ kJ/kg$). The steam generation rate is $10^5\ kg/hr$ and the steam generator efficiency is 88%. Estimate (i) the fuel burning rate in kg/hr if the calorific value of fuel is 21 MJ/kg and (ii) the percentage of total heat absorbed in the economizer, evaporator and superheater. Neglect pressure losses.

(b) A chimney of height 32 m is used for producing a draught of 16 mm of water. The temperatures of ambient air and flue gases are 27°C and 300°C respectively. The coal burned in the combustion chamber contains 81% carbon, moisture 5% and remaining ash. Assuming the volume of burnt gaseous products equivalent to the volume of air supplied, find the percentage of excess air supplied. Neglect losses and assume complete combustion of fuel.

(c) In an engine test, the dry volumetric analysis of the products is as follows:

$$CO_2 = 5.27\%\,, O_2 = 13.38\%\,, N_2 = 81.35\%\,.$$

Assuming that the fuel is a *pure* hydrocarbon and that it is completely burnt, estimate (i) the ratio of carbon to hydrogen in the fuel by mass and (ii) air-fuel ratio by mass.

(2 + 3) + 4 + (2 + 1) = 12

Group – D

6. (a) Explain the term 'compounding' in steam turbine. Why is compounding needed in steam turbine? Explain pressure compounding in an impulse turbine showing the pressure and the velocity variations along the axis of the turbine.

(b) A stage of an impulse steam turbine operates close to the maximum blading efficiency condition. The blades are equiangular and the frictional effects in the blades may be neglected. The mean velocity is 200 m/s and the steam flow rate is 0.75 kg/s. Determine (i) the discharge angle at which steam leaves the blades and (ii) the diagram power associated with the turbine.

(1 + 2 + 2) + (4 + 3) = 12

7. (a) Prove that for 50% reaction turbine, the turbine blades are symmetrical.

(b) A stage of a 50% reaction turbine delivers dry saturated steam at 2.7 bar from the fixed blades at 90 m/s. The mean blade height is 40mm, and the moving blade exit angle is 20°. The axial velocity is ¾th of the mean blade velocity. Steam flow rate is 9000 kg/h. Calculate (i) the wheel speed in rpm, (ii) the diagram power, (iii) the diagram efficiency, and (iv) the enthalpy drop of steam at this stage.

4 + 8 = 12

Group – E

8. (a) A power plant has the following annual factors:
Load factor = 0.75, Capacity factor = 0.60, Utilization factor = 0.65. The maximum demand is 60 MW. Estimate (i) the annual energy production (ii) the reserve capacity over and above the peak load and (iii) the hours during which the plant is not in service per year.

(b) State *six* desirable functions of a moderator of a nuclear reactor power plant.

(2 + 2 + 2) + 6 = 12

9. (a) In a condenser test, the following observations were made:
Vacuum in condenser = 720 $mm\ Hg$;
Barometer reading = 765 $mm\ Hg$;
Mean temperature of condensation= 34°C;
Hot well temperature = 29°C;
Inlet and outlet temperatures of cooling water are 15°C and 25°C respectively; Determine (i) vacuum corrected to standard barometer reading (ii) undercooling of condensate (iii) undercooling efficiency and (iv) condenser efficiency.

(b) State *three* advantages of a pumped storage plant. State *three* functions of a surge tank.

(1 + 1 + 2 + 2) + (3 + 3) = 12