7. (a) Show that the condition for maximum efficiency of a 50% reaction turbine is given by $\eta_{max} = \frac{2\cos^2 \alpha_1}{1+\cos^2 \alpha_1}$ where α_1 is the angle at which the steam enters the blade.

   (b) In a reaction turbine, the fixed blades and the moving blades are of the same shape but reversed in direction. The angle of receiving tips is 35° and angle of the discharging tips is 20°. Find the power developed per pair of blades for a steam consumption of 3.5 kg/s, when the blade speed is 60 m/s. If the heat drop per pair is 12.04 kJ/kg, find the efficiency of the pair.

6 + (3 + 3) = 12

Group – E

8. (a) Draw Otto cycle on p-V and T-s diagram, describe the processes and derive an expression for the efficiency of the cycle.

   (b) A diesel engine operating on the air-standard Diesel cycle has six cylinders of 100 mm bore and 120 mm stroke. The engine speed is 1800 rpm. At the beginning of the compression, the pressure and temperature of air are 1.013 bar and 35°C. If the clearance volume is 1/8th of the stroke volume, and the maximum temperature reached by the cycle is 1500°C, calculate (i) the pressure and temperatures at the cardinal points of the cycle (ii) the compression ratio (iii) the efficiency of the cycle and (iv) power output.
   Assume C_p and C_v of air to be 1.004 and 0.717 kJ/kg K respectively.

4 + (2 + 2 + 2 + 2) = 12

9. (a) What is detonation in SI engine? What is Octane number?

   (b) A four stroke, four cylinder diesel engine running at 2000 rpm develops 60 kW. Brake thermal efficiency is 30% and calorific value of fuel is 42 MJ/kg. The engine has a bore of 120 mm and stroke of 100 mm. Take density of air as 1.15 kg/m^3. The A/F ratio is 15: 1 . The mechanical efficiency is 0.8. Calculate:
   (i) fuel consumption (kg/s)
   (ii) air consumption (m^3/s)
   (iii) indicated thermal efficiency
   (iv) volumetric efficiency
   (v) brake mean effective pressure (bar)
   (vi) mean piston speed.

(2 + 1) + (6 × 1.5) = 12

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.

N. B.: USE OF STEAM TABLE BY STUDENTS IS PERMITTED AFTER VERIFICATION BY THE INVIGILATOR

Group – A
(Multiple Choice Type Questions)

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

   (i) Rankine *efficiency* of a steam power plant
   (a) improves in summer as compared to that in winter
   (b) improves in winter as compared to that in summer
   (c) is unaffected by climatic conditions
   (d) none of these.

   (ii) The main advantage of the Reheat cycle is
   (a) to increase the work output per kg of steam
   (b) to raise the maximum cycle pressure,
   (c) to obtain higher cycle efficiency
   (d) to decrease the moisture content at the turbine outlet.

   (iii) For the same peak pressure and work output
   (a) $\eta_{Otto} > \eta_{Diesel} > \eta_{Dual}$, (b) $\eta_{Otto} > \eta_{Dual} > \eta_{Diesel}$,
   (c) $\eta_{Diesel} > \eta_{Dual} > \eta_{Otto}$, (d) $\eta_{Diesel} > \eta_{Otto} > \eta_{Dual}$.

   (iv) Component of the IC engine which gives power to non-power strokes is
   (a) Spark Plug (b) Flywheel
   (c) Carburettor (d) Fuel injection pump.

   (v) Analysis of flue gas is done by
   (a) Bomb calorimeter (b) Orsat apparatus
   (c) Venturimeter (d) Dual Cycle.

   (vi) The ratio of work done per cycle to the swept volume is called
   (a) compression ratio (b) brake thermal efficiency
   (c) volumetric efficiency (d) mean effective pressure.

(vii) In jet type condensers
(a) cooling water passes through tubes and steam surrounds them
(b) steam passes through tubes and cooling water surrounds them,
(c) steam and cooling water mix
(d) steam and cooling water do not mix.

(viii) In case of pure impulse 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.

(ix) Which of the following boiler accessories removes the entrained liquid water droplets from the steam conveyed to the steam turbine?
(a) Feed pump (b) Injector
(c) Steam separator (d) Superheater.

(x) Maximum power developed 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.

Group – B

2. (a) State briefly the function of the (i) Air preheater and (ii) Superheater.

(b) In a single-heater regenerative cycle, the steam enters the turbine at 30 bar, 400°C and the exhaust pressure is 0.1 bar. The feed water heater is a direct-contact type which operates at 5 bar. Find the (i) thermal efficiency and (ii) steam rate of the cycle (iii) increase in mean temperature of heat addition and (iv) thermal efficiency as compared to the Rankine cycle without regeneration (Pump work may be neglected).

(2 + 2) + (5 + 1 + 1 + 1) = 12

3. (a) In a boiler trial 1250 kg of coal are consumed in 24 hours. The mass of water evaporated is 13000 kg and the mean effective pressure is 7 bar. The feed water temperature is 40°C. The calorific value of coal is taken as 30000 kJ/kg. The specific enthalpy of steam at 7 bar is 2570.7 kJ. Determine (i) equivalent evaporation per kg of coal, and (ii) efficiency of the boiler.

(b) State four 'variable factors' which affect the overall efficiency of a boiler plant.

(c) Describe briefly the 'pulverized fuel firing' method of burning of coal.

(2 + 2) + 4 + 4 = 12

Group – C

4. (a) In what aspects a jet condenser differs from a surface condenser? Mention three adverse effects of air leakage in a condenser.

(b) The outlet and inlet temperatures of cooling water to a condenser are 37.5°C and 30°C respectively. If the vacuum in the barometer is 706 mm of mercury with the barometer reading 760 mm, determine the condenser efficiency.

(c) Explain in brief the principle of operation of an electrostatic precipitator.

(2 + 3) + 3 + 4 = 12

5. (a) What is the difference between higher calorific value (HCV) and lower calorific value (LCV) of a fuel?

(b) The following is the ultimate analysis of a sample of petrol by mass: $Carbon = 85\%, Hydrogen = 15\%$.
Calculate the ratio of air to petrol consumption by mass if the volumetric analysis of the dry exhaust gas is:
$C0_2 = 11.5\%, CO = 1.2\%, \quad O_2 = 0.9\%, N_2 = 86\%$.
Also find the percentage excess air used.

(c) What do you understand by adiabatic flame temperature? How is it controlled?

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

Group – D

6. (a) Steam at 30 bar, 350°C expands through a convergent divergent nozzle. The exit plane pressure is 3 bar. The steam flow rate is 0.5 kg/s and the nozzle efficiency is 80%. Assuming that the velocity at the entry is negligible, determine
(i) the throat and exit areas,
(ii) steam velocity at the exit
(iii) the quality of steam at the exit plane.
The critical pressure may be taken as 0.546.

(b) The velocity of steam entering a simple impulse turbine is 1000 m/s and the nozzle angle is 20°. The mean peripheral velocity of blade is 400 m/s and the blades are symmetrical. If the steam is to enter the blade without shock, what will be the blade angles? Neglecting frictional effects on blades, calculate the tangential force on blades and the diagram power for a mass flow rate of 0.75kg/s. Estimate also the axial thrust and diagram efficiency.

(3 × 2) + (2 + 2 + 2) = 12