Ref. No.: Ex/ME/5/T/524I/2025

BACHELOR OF ENGINEERING IN MECHANICAL ENGINEERING
FIFTH YEAR SECOND SEMESTER- 2025

Subject: GAS TURBINE THEORY

Time: 3 hours | **Full Marks: 100**

Answer any FIVE questions.
All symbols carry their usual meanings.

Q.1 (a) With a neat sketch, briefly explain the working principle of a gas turbine power plant. Plot its cycle on P-v and T-s planes. (5)

(b) A gas turbine has an overall pressure ratio of 10, and the maximum temperature of the cycle is 627°C. Its ambient pressure and temperature are 1bar and 27°C, respectively. The air enters the compressor at a rate of 20 kg/s; the isentropic efficiencies of the compressor and turbine are 80% and 83%, respectively. Neglecting changes in the kinetic energy, mass flow rate of the fuel, and all pressure losses, plot the cycle on T-s plane and calculate: (12)
(i) the temperature and pressure at each node of the cycle,
(ii) the heat supplied to the cycle,
(iii) the heat rejected by the cycle,
(iv) the net power output,
(v) mean effective pressure, and
(vi) the cycle efficiency. Assume any necessary data, if required.

(c) Find maximum efficiency of the above cycle and respective pressure ratio. (3)

Q.2 (a) Draw a layout for a regenerative gas power cycle. Explain its working principle indicating all processes in P-v and T-s planes. (6)

(b) Find an expression for thermal efficiency of an ideal regenerative gas turbine cycle. (10)

(c) Plot variation of thermal efficiencies with pressure ratio for both simple and regenerative gas turbine cycles. Hence, find a limit to the pressure ratio in order to incorporate a regenerator in a turbine cycle. (4)

Q.3 (a) Explain briefly the variation of net work output of a gas turbine cycle with pressure ratio considering T-s diagram. (3)

(b) Show that the maximum specific net work output of a gas power cycle is $w_{net} = C_p\left(\sqrt{T_{max}} - \sqrt{T_{min}}\right)^2$. (12)

(c) Assuming the maximum and minimum temperatures of a gas power cycle are 827°C and 27°C, respectively; calculate optimum value of its pressure ratio, maximum net work output per kg of air and corresponding cycle efficiency. (5)

Q.4 (a) Define stagnation enthalpy. Find an expression for specific stagnation enthalpy of a flow in terms of its static enthalpy and velocity. (3)

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(b) Define Mach number (M). Hence, derive the following relations (9)

$$\frac{T_0}{T} = \left(1 + \frac{\gamma - 1}{2} M^2\right)$$

$$\frac{P_0}{P} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma-1}}$$

$$\frac{\rho_0}{\rho} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{1}{\gamma-1}}$$

(c) An air is stagnated isentropically from a Mach number (M) of 5 and a temperature of -73°C. Hence, find values for stagnation temperature, pressure and density of the flow. Find related sound velocity and corresponding flow velocity. (C_p= 1.005kJ/kg.K and R=0.287 kJ/kg.K) (8)

Q.5 (a) Consider a steady 1-D isentropic flow through a varying cross sectional passage. Show that the flow holds the following relations: (12)

$$\frac{dA}{A} = \frac{dV}{V}(M^2 - 1)$$

$$\frac{dA}{A} = \frac{dP}{\rho V^2}(1 - M^2)$$

(b) Sketch shape of nozzle for both subsonic and supersonic flows based on above relations. (3)

(c) Air is stored in a reservoir at 10 bar and 527°C. The air is then flowing isentropically through a nozzle in order to attain a sonic flow at its exit. Calculate (i) pressure, temperature and density of the air at nozzle exit, and (ii) mass flow rate through the nozzle if the nozzle exit has an area of 5×10^{-4} m^2. (C_p = 1.005kJ/kg.K and R = 0.287 kJ/kg.K) (5)

Q.6 (a) Draw schematically velocity diagrams at inlet and outlet of a moving blade with proper labeling in case of an axial flow compressor. Hence, find an expression for specific work done on the balde. (8)

(b) Consider an axial flow compressor. Its tip diameter is 1.5m; hub diameter is 1.0m. α_1= 30°, β_1= 60°, α_2= 60°, and β_2= 30°. Rotor speed is 3000 r.p.m. Air density is 1.5 kg/m^3. Determine (i) axial velocity, (ii) maximum flow rate, and (iii) power required. (12)

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