Ref. No.: Ex/ME/5/T/524I/2024(S)

**BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING) FIFTH YEAR SECOND SEMESTER SUPPLEMENTARY EXAM - 2024**

**Subject: GAS TURBINE THEORY**

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

**(Answer any five questions)**

Q.1 (a) Consider a gas power plant working on an ideal regenerative Brayton cycle. With a neat layout, explain the cycle labeling all of the necessary components. Plot the cycle on a T-*s* plane indicating all processes. (5+3)

(b) Find an expression for thermal efficiency of the cycle. (12)

Q.2 (a) Under the same maximum and minimum temperatures, neatly plot the Brayton cycle for different pressure ratios (at least three). Hence, plot how the net work output of the Brayton cycle varies with pressure ratio. (3+2)

(b) Consider a gas turbine power plant working on the Brayton cycle. Find an expression for the optimum pressure ratio at maximum net work output. Hence, find related expression of the maximum net work output per kg of air in terms of maximum and minimum temperatures. (15)

Q.3 Consider an air standard Brayton cycle in which air enters compressor at 1.0bar and 27°C. Pressure of the air leaving the compressor is 3.5bar, and temperature at inlet of the turbine is 627°C. Plot the cycle on a T-*s* plane. Determine the following per kg of air: (2×4+3+3+4+2)

(i) temperature and pressure at each node of the cycle,
(ii) heat supplied to the air,
(iii) heat rejected by the cooler,
(iv) net available work at shaft, and
(v) efficiency of the cycle.

Assume R = 0.287 kJ/kg-K, Cp = 1.005 kJ/kg-K, and $\gamma = 1.4$.

Q.4 (a) In case of a steady 1-D compressible isentropic flow, derive the following expression

$$\frac{dA}{A} = \frac{dP}{\rho V^2}(1 - M^2)$$ (10)

All symbols carry usual meaning. Hence, find a shape (converging or diverging) for a nozzle delivers supersonic flow.

(b) Consider a radial centrifugal compressor. Draw both the inlet and outlet velocity diagrams indicating absolute, relative, blade and swirl velocities. Hence, find an expression for the specific work done (Euler's equation) by the blade/impeller in terms of velocities. (3+3+4)

Q.5 A turbo-jet is flying at an altitude of 9500m.

(i) If speed and propulsive efficiency of the turbojet are 800km/hr and 55%, respectively, find absolute velocity of the jet.
(ii) If total drag/propulsive force on the plane is 6100N, then find mass flow rate of the air in $m^3/s$ assuming a density of 0.17 $kg/m^3$ for the air at the altitude of 9500m. (8+8+4)
(iii) Find thrust power developed by the jet.

Q.6 Write short notes (any four). (5×4=20)

(a) Working principle of a turbo-jet engine with a neat sketch
(b) Working principle of a turbo-prop engine with a neat sketch
(c) Rocket engine
(d) Air conditioning in an aircraft
(e) Consider compressible flow through a convergent-divergent nozzle. Explain formation of possible shock waves by a neat sketch.