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Question Paper Code : P 1418

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2009.

Fifth Semester

Mechanical Engineering

ME 1303 — GAS DYNAMICS AND JET PROPULSION

(Regulation 2004)

Time : Three hours

Maximum : 100 marks

Gas tables can be permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Express the stagnation enthalpy in terms of static enthalpy and velocity of flow.

2. When air is released adiabatically from a tyre, the temperature of air at the nozzle exit is 37°C below that of air inside the tyre. Neglecting irreversibility calculate the exit velocity of air.

3. Sketch the isentropic and actual expansion through a nozzle and give the expression for nozzle efficiency.

4. Explain the difference between Fanno flow and isothermal flow.

5. Sketch the Rayleigh line on the T-s plane and explain the significance of it.

6. Define : "Strength of a shock wave".

7. Explain how the pitot tube could be used to measure the Mach number in supersonic flow.

8. Sketch the thrust and propulsive efficiency variation against the speed ratio for a turbo jet engine.

9. Briefly explain thrust augmentation and any two methods of achieving it.

10. Give any two advantages and disadvantages of rockets compared to air breathing engines.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Air is discharged from a receiver at $P_0 = 6.91$ bar and $T_0 = 325$ °C, through a nozzle to an exit pressure of 0.98 bar. If the flow rate is 3600 kg/hour, determine for isentropic flow, (1) area, pressure and velocity at throat, (2) area and Mach number at exit and (3) maximum possible velocity. (10)

(ii) Deduce an expression for sonic velocity in terms of the properties of air. (6)

Or

(b) Sketch the effect of disturbance in still air as it moves from rest to supersonic velocity for the following Mach numbers: M = 0, M = 0.5, M = 1.0, M = 2. Explain in detail the observed phenomena. (16)

12. (a) Starting from the continuity equation derive the expression for the area variation in terms of Mach number and velocity variation and hence obtain the shape (geometry) for both subsonic and supersonic nozzles and diffusers. (16)

Or

(b) In an isentropic flow diffuser the inlet area is 0.15 m^2. At the inlet velocity 240 m/s, static temperature = 300K, and static pressure 0.7 bar. Air leaves the diffuser with a velocity of 120 m/s. Calculate at the exit the mass flow rate, stagnation pressure, stagnation temperature, area and entropy change across the diffuser. (16)

13. (a) Air enters a constant area duct at $M_1 = 3$, $p_1 = 1$ atm, and $T_1 = 300K$. Inside the duct the heat added per unit mass is $q = 3\times10^5$ J/kg. Calculate the flow properties $M_2, p_2, T_2, \rho_2, T_{02}$, and p_{02} at the exit. (16)

Or

(b) Air at an inlet temperature of 60°C flows with subsonic velocity through an insulated pipe having inside diameter of 50 mm and a length of 5 m. The pressure at the exit of the pipe is 101 kPa and the flow is choked at the end of the pipe. If the friction factor 4f = 0.005, determine the inlet Mach number, the mass flow rate and the exit temperature. (16)

14. (a) A convergent divergent nozzle is designed to expand air from a reservoir in which the pressure is 800 kPa and temperature is 40°C to give a mach no at exit of 2.5 .The throat area is 25cm^2. Find (i) mass flow rate, (ii) exit area, and (iii) when a normal shock appears at a section where the area is 40 cm^2 determine the pressure and temperature at exit. (16)

Or

(b) (i) Prove that for a normal shock $p_y/p_x = \left(1 + K M_x^2\right)/\left(1 + K M_y^2\right)$ where K is the ratio of specific heats for air. (6)

(ii) A pitot tube kept in a supersonic wind tunnel forms a bow shock ahead of it. The static pressure upstream of the shock is 16 kPa and the pressure at the mouth is 70 kPa. Estimate the Mach number of the tunnel. If the stagnation temperature is 300°C, calculate the static temperature and total pressure upstream and downstream of the tube. (10)

15. (a) A turbojet propels an aircraft at a speed of 900 km/hour, while taking 3000 kg of air per minute. The isentropic enthalpy drop in the nozzle is 200 kJ/kg and the nozzle efficiency is 90%. The air-fuel ratio is 85 and the combustion efficiency is 95%. The calorific value of the fuel is 42,000 kJ/kg. Calculate :

(i) The propulsive power, (ii) Thrust power, (iii) Thermal efficiency and (iv) Propulsive efficiency. (16)

Or

(b) (i) Deduce expressions for propulsive efficiency specific impulse and overall efficiency of a rocket engine. (6)

(ii) A rocket has the following data: propellant flow rate 5.0 kg/s; nozzle exit diameter = 10 cm; nozzle exit pressure = 1.02 bar; ambient pressure 1.013 bar; thrust chamber pressure = 20 bar; thrust = 7 kN. Determine the effective jet velocity, actual jet velocity, specific impulse and the specific propellant consumption. (10)
