# R 8489

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2006.

Fifth Semester

Mechanical Engineering

ME 333 — GAS DYNAMICS AND SPACE PROPULSION

Time : Three hours Maximum : 100 marks

Use of Standard Gas Tables Permitted.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Draw the Mach Cone and identify its salient features.
2. What is the effect of Mach number on compressibility?
3. What is Fanno line?
4. How do the flow properties change in Rayleigh flow?
5. What is meant by Mach reflection?
6. Differentiate between impulse and specific impulse.
7. What are unique features of jet engine combustion chambers?
8. What are the limitations of jet engine?
9. Compare the propulsive efficiency of Jet engine with that of rocket engine.
10. What is the need for multi–stage rocket?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Deduce the expression for the change in area for isentropic flow and identify the geometric shapes for nozzles and diffusers. (10)

(ii) An aircraft is flying at an altitute of 12,000 meters (T = 216.65 K, p = 0.193 bar) at a Mach number of 0.82. The cross–sectional area of the inlet diffuser before the L.P compressor stage is 0.5 $m^2$. Determine the mass of air entering the compressor per second, the speed of the aircraft and the stagnation pressure and temperature of air the diffuser entry. (6)

Or

(b) (i) Derive the expression for the area expansion ratio of nozzles. (10)

(ii) A Freon–turbine has to use a maximum flow rate of 5 kg/s of Freon employing a ring of convergent nozzles of total exit area of cross–section of 100 $cm^2$. The pressure in the nozzle entry space is $20 \times 10^5$ $N/m^2$. Taking $C_p$ = 0.845 kJ/kg K, $\gamma$ = 1.2 calculate stagnation temperature, static pressure and temperature at the nozzle exit, and Mach number at the nozzle exit. (6)

12. (a) (i) Describe how the property changes in fanno flow with suitable diagram and justifications. (6)

(ii) A circular duct passes 8.25 kg/s of air at an exit Mach number of 0.5. The entry pressure and temperature are 3.45 bar and 38°C respectively and the coefficient of friction 0.005. If the Mach number at entry is 0.15, determine, the diameter of the duct, length of the duct, pressure and temperature at the exit and stagnation pressure loss. (10)

Or

(b) (i) Outline the assumptions made in Rayleigh flow and explain their implications. (6)

(ii) A combustion chamber in a gas turbine plant receives air at 350 K, 0.55 bar and 75 m/s. The air–fuel ratio is 29 and the calorific value of the fuel is 41.87 MJ/kg. Taking $\gamma$ = 1.4 and $R$ = 0.287 kJ/kg K for the gas determine the initial and final Mach numbers, final pressure, temperature and velocity of the gas, percent stagnation pressure loss in the combustion chamber, and the maximum stagnation temperature attainable. (10)

13. (a) (i) Show that flow after normal shock is always subsonic. (8)

(ii) The ratio of the exit to entry area in a subsonic diffuser is 4.0. The Mach number of a jet of air approaching the diffuser at $p_0$ = 1.013 bar, T = 290 K is 2.2. There is a standing normal shock wave just outside the diffuser entry. The flow in the diffuser is isentropic. Determine at the exit of the diffuser. Mach number, temperature, and pressure. What is the stagnation pressure loss between the initial and final states of the flow? (8)

Or

(b) (i) Plot and explain the wave pattern at the exit of a overexpanded nozzle. (6)

(ii) Determine the temperature and pressure field around a symmetric double wedge of 20° included angle kept at 15° angle of attack to a supersonic stream of Mach number 2.5, by the shock–expansion theory. (10)

14. (a) (i) Explain the working of turbofan engine with a suitable sketch. (6)

(ii) An aircraft flies at 1000 kmph. One of its turbojet engines takes in 40 kg/s of air and expands the gases to the ambient pressure. The air–fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/kg. For maximum thrust power determine jet velocity, thrust, specific thrust, thrust power and TSFC. (10)

Or

(b) (i) Classify aircraft and rocket propulsion engines and identify their working principle with at least one important feature for each of them. (8)

(ii) Diameter of an aircraft propeller is 4.0 m. The speed ratio is 0.8 at a flight speed of 450 kmph. If the ambient conditions of air at the flight altitude are T = 256 K and p = 0.54 bar. Determine the propulsive efficiency, thrust and thrust power. (8)

15. (a) (i) Deduce the expression for the thrust and effective jet velocity of a rocket engine. (6)

(ii) A rocket nozzle has a throat area of 18 $cm^2$ and combustion chamber pressure of 25 bar. If the specific impulse is 127.42 seconds and weight flow rate 44.145 N/s. Determine the thrust coefficient, propellant weight flow coefficient, specific propellant consumption, and the characteristic velocity. (10)

Or

(b) (i) Derive the expression for the orbital velocity and hence calculate the orbital and escape velocities of a rocket at mean sea level and an altitude of 300 km (assume the radius of earth = 6341.6 km). (8)

(ii) A missile has maximum flight speed to jet speed ratio of 0.211 and specific impulse = 2204 s. Determine for a burn out time of 8s, effective jet velocity, mass ratio, maximum flight speed and altitude gain during powered and coating flights. (8)

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