



B.E DEGREE EXAMINATIONS: MAY 2015

(Regulation 2009)

Fifth Semester

MECHANICAL ENGINEERING

MEC112: Gas Dynamics and Jet Propulsion

(Use of Approved Gas Table is Permitted)

Time: Three Hours

Maximum Marks: 100

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

- The angle between Mach lines and direction of motion of body is called
 - Mach wave angle
 - Mach cone angle
 - Mach angle
 - Angle of zone of silence.
- Crocco number C_r is the ratio of
 - C / C_{\max}
 - C_{\max} / CWhere C = fluid velocity,
 C_{\max} = max. fluid velocity
 - a / a_{\max}
 - a_{\max} / awhere a = air velocity,
 a_{\max} = max. air velocity
- An isentropic, converging-diverging nozzle operates with stagnation conditions 400 kPa and 500 K. This nozzle has a throat area of 0.01 m^2 and is choked. What is the mass flow rate through this nozzle?
 - 5.01 kg/s
 - 7.23 kg/s
 - 8.32 kg/s
 - 9.81 kg/s
- If the mach number is more than 5, then the region is called as
 - Subsonic region
 - Sonic region
 - Supersonic region
 - Hypersonic region
- A steady one-dimensional flow in a constant area duct with friction in the absence of work and heat transfer is known as
 - Rayleigh flow
 - Isothermal flow
 - Fanno flow
 - Isentropic flow

6. In Fanno and Rayleigh flows, choking occurs when Mach number (M) is
 - a) $M > 1$
 - b) $M \ll 1$
 - c) $M < 1$
 - d) $M = 1$
7. After normal shock
 - a) Temperature drops
 - b) Change in entropy increases
 - c) Stagnation enthalpy increases
 - d) Stagnation pressure increases
8. The strength of shock wave is
 - a) $(p_y - p_x) / p_x$
 - b) $p_x / (p_y - p_x)$
 - c) $p_y / (p_y - p_x)$
 - d) $(p_x - p_y) / p_x$
9. A rocket works with maximum overall efficiency when air-craft velocity is _____ the jet velocity.
 - a) equal to
 - b) one-half
 - c) double
 - d) Three times
10. RAM effect takes place when the air is passed through
 - a) Turbine
 - b) Nozzle
 - c) Diffuser
 - d) Combustion chamber

PART B (10 x 2 = 20 Marks)

11. What is the sonic speed in air at 21°C under Isothermal and Isentropic conditions?
12. Explain Mach cone and Mach angle?
13. Draw the variation of Mach number along the length of a convergent divergent duct when it acts as a (a) Nozzle (b) Venturi.
14. When does the maximum mass flow occur for an isentropic flow with variable area?
15. How does the flow behave when the heat transfer exceeds the maximum in Rayleigh flow?
16. Explain briefly the choking in fanno flow.
17. What is Prandtl-Meyer relation? State its significance.
18. Shown a normal shock in h-s diagram with the help of Rayleigh line and Fanno line.
19. Differentiate between pressure thrust and momentum thrust.
20. Compare liquid propellant and solid propellant rockets.

PART C (5 x 14 = 70 Marks)

21. a) (i) An aircraft is flying at an altitude of 12km ($T=216.65K$, $p = 0.193$ bar) at a Mach number of 0.80. The cross sectional area of the inlet diffuser before the low pressure compressor stage is 0.5 m^2 . Determine a) the mass of air entering the compressor per second b) the speed of the aircraft and c) the stagnation pressure and temperature of air at the diffuser entry. (8)

- (ii) Derive an equation for the mass flow rate in terms of Mach number. (6)

(OR)

- b) (i) What is the effect of Mach number (M) on the compressibility? And prove for $\gamma = 1.4$. (10)

$$\frac{p_0 - p}{\frac{1}{2}\rho_0 c^2} = 1 + \frac{1}{4}M^2 + \frac{1}{40}M^4 + \dots$$

- (ii) Air at 200kPa flows at a velocity of 60 m/s. Find the mach number at a point where its density is 2.95 kg / m^3 . (4)

22. a) A supersonic nozzle expands air from $p_0 = 25 \text{ bar}$ and $T_0 = 1050 \text{ K}$ to an exit pressure of 4.35 bar ; the exit area of the nozzle is 100 cm^2 . Determine a) throat area b) pressure and temperature at the throat c) temperature at exit d) exit velocity as fraction of the maximum attainable velocity and e) mass flow rate .

(OR)

- b) A conical air diffuser has an inlet area of 0.25 m^2 and an exit area of 0.50 m^2 . Air enters the diffuser with a static pressure of 0.2 MPa , static temperature of 40° C and a velocity of 270 m/s . Calculate
- the mass flow rate of air through the diffuser
 - the mach number, static temperature and pressure of the air leaving the diffuser
 - the net thrust acting upon the diffuser due to diffusion.

23. a) A long pipe of 25 mm diameter has a mean coefficient of friction of 0.004 . Air enters the pipe at a Mach number of 2.5 , stagnation temperature 310 K and static pressure of 0.50 bar . Determine for a section at which the Mach number reaches 1.5
- static pressure and temperature
 - stagnation pressure and temperature
 - velocity of air
 - distance of this section from the inlet and
 - mass flow rate of air. Take $\gamma = 1.4$ and $R = 287 \text{ J / kg}^\circ\text{K}$

(OR)

- b) Air enters in a constant area duct at $M_1 = 3.5$, $p_1 = 1 \text{ atm}$ and $T_1 = 27^\circ\text{C}$. Inside the duct the heat added per unit mass is $q = 300 \text{ kJ / kg}$. Calculate the flow properties M_2 , p_2 , T_2 , T_{02} , ρ_2 and p_{02} at the exit.

24. a) (i) A convergent-divergent air nozzle has exit to throat area ratio of 3. A normal shock appears at the divergent section where the existing area ratio is 2.5. Find the Mach number before and after the shock. If the inlet stagnation properties are 500 kPa and 450 K, find the properties of air at exit and entropy increase across the shock. (10)

(ii) Explain the phenomenon of normal shock and oblique shock. (4)

(OR)

b) A supersonic nozzle is provided with a constant diameter circular duct at its exit. The duct diameter is same as the nozzle exit diameter. Nozzle exit cross section is three times that of its throat. The entry conditions of the gas ($\gamma = 1.4$ and $R = 0.287 \text{ kJ / kg } ^\circ\text{K}$) are $p_o = 12 \text{ bar}$, $T_o = 550^\circ \text{ K}$. Calculate the static pressure, Mach number and the velocity of the gas in the duct: (a) When the nozzle operates at its design condition (b) when a normal shock occurs at a section in the diverging part where the area ratio $A / A^* = 2.5$.

25. a) A turbojet propels an aircraft at a speed of 950 km / hr while taking 3000 kg of air per min. 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 CV of the fuel is 42kJ / kg. Calculate a) propulsive power b) thrust power c) thermal efficiency and d) propulsive efficiency

(OR)

b) (i) With the help of neat sketch, explain any one arrangement used for fuel feeding in liquid propellant rocket systems. (4)

(ii) With neat sketches explain the principle of operation of Turbo fan engine and Turbo propeller engine. (10)
