Exam Date & Time: 09-Dec-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

SEVENTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, DECEMBER 2023

Jet Propulsion and Rocket Technology [MME 4071]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions. Section Duration: 180 mins

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) Explain the bleed burn cycle of Thrust Augmentation. (3)

A)

B) The effective jet velocity from a jet engine is 3200 m/s. The forward flight velocity is 1400 m/s and the air flow rate is 65 kg/s. Calculate (2)

(i) Thrust Power (ii) Propulsive efficiency

C) Determine the specific work output, fuel consumption and cycle efficiency for a simple cycle gas turbine with a free power turbine given the following specifications: (5)

Compressor pressure ratio:	12
Turbine inlet temperature:	1350 K
Isentropic efficiency of compressor:	0.86
Isentropic efficiency of each turbine:	0.89
Mechanical efficiency of each shaft:	0.99
Combustion efficiency:	0.99
Combustion chamber pressure loss:	6% compressor delivery pressure
Exhaust pressure loss:	0.03 bar
Ambient pressure:	1 bar
Ambient temperature:	288 K

2) A) It is required to install engines to an aircraft running at an altitude where ambient temperature and pressure are 236 K and 0.38 bar respectively. The 2 possible engines are Turbojet and Ramjet. The Turbojet has a maximum operating temperature of 1300 K with a compression ratio of 10. The maximum operating temperature of Ramjet is 2400 K. The aircraft has to run at a speed of Mach 1.2. Considering there are no aerodynamics losses at any component in both the turbojet and ramjet engines (i.e. all components have 100% efficiency), compare the TSFC of both these engines and suggest a suitable engine for the application. (5)

Assume $P_e = P_a$, $\gamma_a = \gamma_g = 1.4$, $C_{pa} = C_{pg} = 1.0$ kJ/kgK, Heating value of fuel = 45 MJ/kg.

Hint: Use f=$\dot{m}_f / \dot{m}_a$ wherever applicable.

B) With a neat sketch, explain the working of a turbo-shaft engine and its applications. (3)

C) Explain the effects of regeneration in a gas turbine unit. (2)

3) A) A rocket has the following characteristics:

Initial mass: 180 kgs

Mass after rocket operation: 110 kgs

Payload: 70 kgs

Operating duration: 5 seconds

Average specific impulse of propellant: 200 seconds (4)

Determine the propellant mass fraction, propellant flow rate, thrust-to-weight ratio, acceleration of the vehicle, and the total impulse.

B) Using first principles, prove that the semi-divergence angle of a conical nozzle is optimum at 15°. (3)

C) From first principles, derive an expression to find expansion ratio of nozzle. (3)

4) A) Discuss the drawbacks associated with liquid propellant tanks having a gas pressure feed system. How are those drawbacks addressed in turbopump feed systems? With a neat sketch, explain the working of a Gas generator combustion cycle turbopump feed system. (4)

B) Give the advantages of Gelled propellants over solid or liquid propellants. (2)

C) A rocket traverses from 0 to 20 km in altitude. The nozzle is designed for 9 km altitude. The chamber pressure is 10 MPa and $\gamma_g = 1.3$. Area of throat is 0.2 m^2. Determine (4)

(i) Nozzle expansion ratio

(ii) Nozzle exit area A_e

(iii) Optimum thrust coefficient at 9 km altitude

Take T_a = -46.6 °C and P_a = 0.306 bars

5) With a neat sketch, explain the working of a Hall effect thrusters.

. (3)

A)

B) A satellite system is to be designed for space travel to outer solar system. Among the advanced propulsion techniques of solar sails and ion-propulsion thrusters, which would be preferred for a duration of operation of 20 years? Justify your answers. (4)

C) With a neat sketch, explain the working of an Arcjet thruster. What are its limitations? (3)

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