Exam Date & Time: 15-Jan-2024 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

SEVENTH SEMESTER B.TECH MAKE UP END SEMESTER EXAMINATIONS, JAN 2024

Jet Propulsion and Rocket Technology [MME 4071]

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

A

Answer all the questions.

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

1) Explain the Thrust Augmentation process using an Afterburner. (3)

A)

B) A turbojet uses the fuel having calorific value of 44 MJ/kg. The fuel consumption is 0.2 kg per hour per N of thrust, when the thrust is 12 kN. The aircraft velocity is 600 m/s and the mass of air passing through the compressor is 30 kg/s. Calculate the air-fuel ratio and overall efficiency. (2)

C) In a gas turbine plant, air enters the compressor at 1 bar and 7° C. It is compressed to 4 bar with an isentropic efficiency of 82%. The maximum temperature at the inlet to the turbine is 800° C. The isentropic efficiency of the turbine is 85%. The calorific value of the fuel is 43.1 MJ/kg. The heat losses are 15% of the calorific value. Calculate the following:

1) Compressor work in kJ/kg

2) Heat supplied in kJ/kg

3) Turbine work in kJ/kg

4) Net work in kJ/kg

5) Thermal efficiency

6) Air/Fuel ratio

7) Specific fuel consumption in kg/kW-hr

8) Ratio of compressor work to turbine work

(5)

2) It is required to install engines to an aircraft running at an altitude where ambient temperature and pressure are 205 K and 11.6 kPa respectively. The 2 possible engines are **Turbojet** and **Ramjet**. The Turbojet has a maximum operating temperature of 1400 K with a compression ratio of 12. The maximum operating temperature of Ramjet is 2500 K. The aircraft has to run at a speed of Mach 1.5. 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)

A)

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 mixed flow turbofan engine. (3)

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

3) A rocket has the following characteristics:

A) Initial mass: 200 kgs

Mass after rocket operation: 130 kgs

Payload: 110 kgs

Operating duration: 3 seconds (4)

Average specific impulse of propellant: 240 seconds

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

B) Using first principles, justify the use of bell-shaped conical nozzles. (3)

C) Explain the 3 modes of expansion in a rocket nozzle. (3)

4) With a neat sketch, explain the working of a Staged combustion cycle turbopump feed system. Highlight the differences between staged cycle and gas generator cycle. (4)

A)

B) Give the advantages of Hybrid propellant systems. (2)

C) A rocket traverses from 0 to 60 km in altitude. The nozzle is designed for 24 km altitude. The chamber pressure is 12 MPa and $\gamma_g = 1.3$. Area of throat is 0.15 m^2. Determine

(i) Nozzle expansion ratio

(ii) Nozzle exit area A_e (4)

(iii) Optimum thrust coefficient at 24 km altitude

Take T_a = -56.3 °C and P_a = 0.029 bars

5) With a neat sketch, explain the working of an Ion propulsion system. (3)

A)

B) A satellite system is to be designed for space travel to the planet Neptune. Among the advanced propulsion techniques of solar sails and Arcjet thrusters, which would be preferred for a duration of operation of 8 years? Justify your answers. (4)

C) With a neat sketch, explain the working of Solar Sails. What are its limitations? (3)

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