Exam Date & Time: 23-Nov-2022 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

MANIPAL INSTITUTE OF TECHNOLOGY
VII SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV 2022

Rocket Propulsion [AAE 4067]

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

A

Answer all the questions.

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

1) Compare chemical rockets based on their specific impulse. (2)

A)

B) Explain burning rate in a solid rocket. What are the methods used to improve the burning rate? (3)

C) The following measurements were made in a sea level test of a solid propellant rocket motor:

Burn duration: 35 s

Initial mass before test: 2500 kg

Mass of rocket motor after test: 215 kg

Average thrust: 75,250 N

Chamber pressure: 7.50 MPa

Nozzle exit pressure: 0.065 MPa (5)

Nozzle throat diameter: 0.0855 m

Nozzle exit diameter: 0.2705 m

Determine propellant mass flow rate, exhaust jet velocity, characteristic jet velocity, effective jet velocity and specific impulse at sea level and effective jet velocity and specific impulse at 1200 and 25,000 m altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. The ambient pressures at 1200 m and 25,000 m are 0.188 bar and 0.0218 bar, respectively.

2) Tabulate the variation of grain burning rates for a propellant with a=0.060 and n=0.4 for pressures 500, 1500, and 2500 kPa. (2)

A)

B) Briefly describe the components of a solid propellant grain. (3)

C) Derive rocket equation. For a multistage rocket engine with 'n' stages, derive the expression for burnout velocity in terms of propellant mass ratio. (5)

3) Consider two rockets P and Q fired vertically up with identical specific impulses and a payload of 5 kg. Rocket P has two identical stages, and each stage has 200 kg of propellant and 20 kg of structural mass. Rocket Q has a single stage with 400 kg of propellant and 40 kg of structural weight. Neglecting drag and gravity effects, find the ratio of change in velocity of P with respect to Q. (2)

A)

B) With a schematic of hybrid rocket engine, write a short note on the fuel-oxidizer combinations used and the advantages and disadvantages of hybrid rockets over solid and liquid rockets. (3)

C) Briefly describe (a) the assumptions used in hybrid combustion theory and (b) the combustion process or hybrid ballistics. (5)

4) A solid propellant rocket producing 55 MN thrust is fired for 170 s. The specific impulse of the rocket is 2665 Ns/kg. Find the mass of propellant burned during the rocket operation and the effective exhaust velocity. (2)

A)

B) Briefly describe the following:

a. Ullage

b. Expulsion efficiency

c. Sloshing

d. Regressive burning

e. Deflagration limit

f. Web fraction

(3)

C) With neat schematics, explain the under-expanded and over-expanded operation of a C-D nozzle. Also point out the situations where a Mach disk and a Barrel shock wave are formed. (5)

5) The exhaust gas (γ=1.3) at pressure 100 kPa and temperature 600 K enters into a C-D nozzle with inlet Mach number 0.8. If the exit pressure is 70 kPa, find the exit Mach number and temperature. (2)

A)

B) Briefly describe the stage combustion engine cycle used in a liquid rocket engine, with a neat sketch. (3)

C) The exhaust gas at stagnation pressure of 2 MPa and stagnation temperature of 1400 K enters a C-D nozzle having a throat area of 0.1 m^2. Determine the total thrust produced by the isentropic chocked nozzle when the exit and atmospheric pressure are estimated to be 30 kPa and 100 kPa, respectively. (Consider $\gamma = 1.25$ and Molecular mass of gas, M = 28 kg/kmol). (5)

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