INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY THIRUVANANTHAPURAM

DEPARTMENT OF AEROSPACE ENGINEERING

M.TECH. DEGREE COURSE MIDTERM MAR 2025

AE 734 DESIGN AND MODELING OF ROCKET PROPULSION SYSTEMS

Date: 07-03-2025 Time: 9:30 AM-11:30 AM Max. Marks: 30

(Handwritten Notes Allowed, State All Assumptions clearly)

1. A solid propellant is cast to generate hot gases at a temperature of 3100 K, a molecular mass of 23 kg/kmol and a specific heat ratio of 1.34. The combustion chamber pressure is 7 MPa. The gases are expanded in the nozzle to the ambient pressure of 0.1 MPa. Determine (i) Characteristic velocity (C*), (ii) Characteristic Thrust coefficient (C°_F), (iii) Thrust Coefficient (C_F) in vacuum, and (iv) Specific impulse in vacuum. (v) Also determine the mass flow rate of the propellants that must burn to generate a thrust of 10^3 kN in vacuum if the C* efficiency is 0.97, and the thrust coefficient-efficiency is 0.92

(7 marks)

2. In a liquid rocket combustion chamber, the temperature of the products is 3300 K, the molecular weight is 22 kg/kmol and the specific heat ratio is 1.22. The thrust coefficient is 1.6 and the thrust is 1000 kN. The effective area of the liquid injector is 0.02 m^2 with an effective propellant density of 800 kg/m^3 at the injection plane. Determine P_1/P_c at the injection plane of the combustion chamber. You can assume the ratio of throat area to chamber cross section area, A_t/A_c as 0.5.

(7 marks)

3. A two stage, solid-propellant sounding rocket has the following properties.
   First stage: m_0 = 249.5 kg, m_f = 170.1 kg, m_e = 10.61 kg/s, Isp = 235 s
   Second stage: m_0 = 113.4 kg, m_f = 58.97 kg, m_e = 4.053 kg/s, Isp = 235 s
   Delay time between burnout of first stage and ignition of second stage: 2 seconds.
   As a preliminary estimate, neglect drag and the variation of earth's gravity with altitude to calculate the maximum height reached by the second stage after burnout.

(8 marks)

4. Consider a rocket comprising of three similar stages (i.e., each stage has the same specific impulse, structural ratio and payload ratio). The common specific impulse is 330 s. The total mass of the vehicle is 150 000 kg, the total structural mass (empty mass) is 20 000 kg and the payload mass is 11 000 kg. Calculate
   (a) The mass ratio n and the total Δv for the three-stage rocket.
   (b) m_{p1}, m_{p2}, and m_{p3}
   (c) m_{E1}, m_{E2} and m_{E3}
   (d) m_{o1}, m_{o2} and m_{o3}

(8 marks)