INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY THIRUVANANTHAPURAM

DEPARTMENT OF AEROSPACE ENGINEERING

M.TECH. DEGREE COURSE MIDTERM MAR 2026

AE 718 SPACE MISSION DESIGN

Date: 12-03-2026 Time: 9:30 AM 11:30 AM Max. Marks: 30

(Handwritten Notes Allowed, State All Assumptions clearly)

1. The payload mass of a rocket is 5000 kg and the payload fraction of the launch vehicle is 0.05. The structural ratio, ε=0.15. The Isp is 300 s. Consider constant g_o = 9.8 m/s^2. For a Single Stage and a restricted two stage vehicle, compare the (i) total 'delta V' provided by the vehicle, (ii) empty mass of the launch vehicle, and (iii) total propellant mass

(10 marks)

2. A rocket is designed to generate 6 MN of thrust at ideal conditions. The pressure in the combustion chamber is 8 MPa and the temperature is 3000 K. The molecular weight of the combustion products are 23 kg/k-mole and the specific heat ratio of the gaseous mixture is 1.20. The nozzle is designed to operate at 4 km altitude. Determine (i) ideal specific impulse, (ii) mass flow rate and (iii) throat and exit diameter. If the rocket operates at very high altitude where the ambient pressure is nearly zero, determine the corresponding (iv) specific impulse and mass flow rate.

$h_{altitude}$ (km)	0	4	8	12	16	20
Pa (N/m^2)	101325	61660	35651	19399	10353	5529

(10 marks)

Note: *Attempt Qn 3 only after you complete Qn 1 and Qn 2. Don't panic on Qn3. Refer to your notes and procedurally try to solve the problem. Approach to the design problem in Qn 3.will be given maximum weightage.*

3. A rocket is launched vertically at an initial pitch angle of 90°. The mass of the rocket is 210 kg and h_{cg} =2 m. Consider constant thrust of 10.3 kN and average ISP of 275 sec. The launch station geodetic latitude is 8.54° and geocentric longitude is 76.86°. The launch azimuth is 225°. In phase-1 the rocket first rises vertically for 1 sec after lift-off. In phase -2, it undergoes a constant pitch rate maneuver at -1 deg/s for another 1 sec. In phase-3, it is subjected to gravity turn (all aerodynamic angles are zero) for another 1 sec. Tabulate and compare the following parameters at the end of each phase: (i) Altitude, (ii) magnitude of relative velocity, (iii) Mach number, (v) relative flight path angle, (vi) inertial longitude, (vii) relative longitude, (viii) geocentric latitude and (ix) pitch angle.

(Assume constant drag coefficient C_D=0.6, constant atmospheric pressure, density and temperature of 1 bar, 1.22 kg/m^3 and 25 deg C, constant gravity of 9.8 m/s^2 acting along the radius vector in the opposite direction. Consider each time step of 1 sec (h = 1 sec) and use either forward Euler or RK4. Earth's parameters, R_e=6378137m, R_p= 6356752m, Angular speed= 7.292115 x 10^{-5} rad/s)

Note: *State clearly the assumptions involved in employing any other parameters*

(10 marks)

Forward Euler: $y_{n+1} = y_n + h*f(t_n, y_n)$; h- time step, $f(t_n, y_n)$- slope at (t_n, y_n)

+ (-2 dy)