AE 330/708 Assignment 5

Due date: 10-11-2020, 11.59 pm

1] Following are the details of solid rocket motor:
Sea level thrust = 8896.4 N, Chamber pressure = 6.89 MPa, Duration = 10 sec, Ambient temperature = 294 K, Propellant = Ammonium Nitrate-Hydrocarbon with following properties:
T_1 = 1755.3 K, r = 2.54 mm/s, k = 1.22, MW = 22, ρp = 1550 kg/m^3.
Determine specific impulse, throat area, exit area, mass flow rate, propellant weight, total impulse, burning area. (C_F =1.57, ε = 7.8)

2] Following are details of a solid propellant burning:

Propellant specific gravity	1.71
Chamber pressure	14 MPa
Temperature coefficient	17.21 mm/s
Specific heat ratio	1.27
Chamber gas temperature	2220 K
Molecular mass	23 kg/kg-mol
Burning rate exponent, n	0.3

Design a simple rocket motor for the conditions given above for a ground thrust of 5000 N (assume optimum expansion at sea level pressure of 0.1 MPa) and a duration of 15 sec. ($r = aP_1^n$ where r is in mm/s and P_1 is in MPa)

3] A monopropellant thruster is using hydrazine (N_2H_4) as monopropellant. Liquid hydrazine is sprayed on the catalyst (iridium) at 298 K. Liquid hydrazine decomposes into ammonia and nitrogen gas (here it is assumed that no ammonia decomposes into hydrogen).

Chemical species	Heat of formation (ΔH_f) (MJ/kmol)	Cp (kJ/kmol.K)
N_2H_4	50.3	--
NH_3	-45.9	45.06
N_2	--	38

A thruster is to be designed to produce a vacuum thrust of 1 kN. The steady chamber pressure is expected to be 1 MPa and the nozzle exit pressure is to be maintained at 2 kPa. The specific heat ratio is 1.25. Design the suitable nozzle. Determine:
The molecular weight of the gases and hence the characteristic velocity of the gases through the nozzle, The nozzle expansion ratio, Nozzle exit velocity, The mass flow rate, Throat diameter and nozzle exit diameter, Vacuum specific impulse.

4] A semi-cryogenic engine burns liquid kerosene and oxygen in its combustor at φ=1. Kerosene can be approximated by iso-octane (C_8H_{18}). For simplicity, assume vapours of kerosene and gaseous oxygen are present at reference temperature of 298 K prior to combustion and combustion is complete. Standard heat of formation of octane is -249.95 kJ/mol.

	Heat of formation (kJ/mol)	Cp kJ/kmol.K
CO_2	-393.978	60.43
H_2O	-241.997	53.9

Assume that the cooling system brings down the chamber temperature to 80% of adiabatic flame temperature without change in any other thermodynamic parameter. This chamber temperature is to be used for the rest of the calculations.
A thruster is to be designed to produce a vacuum thrust of 100 kN. The steady chamber pressure is expected to be 6 MPa and the nozzle exit pressure is to be maintained at 30 kPa. The specific heat ratio is 1.22. Determine the characteristic velocity of the gases through the nozzle, the nozzle expansion ratio, mass flow rates of fuel and oxidizer and vacuum specific impulse.