BITS Pilani, Pilani Campus

Comprehensive Exam, Second Semester (2021-2022)

ME F418: Rocket and Spacecraft Propulsion

(Part A, **Closed book**)

Part A, Marks – 12 — 13th May 2022, Time: 60 minutes

Note: All questions are compulsory and there is no negative marking. Write the answers in the specified space. No extra answers sheet will be provided

Name - ____________________________ Signature - _______________________

ID No. - ____________________________

1. The speed of the sound at room temperature will be maximum in which of the following gas

(a) oxygen (b) hydrogen

(c) air (d) nitrogen [0.5]

2. The payload mass fraction for a rocket will increase [0.5]

(a) With increasing incremental velocity

(b) With increasing specific impulse

(c) With decreasing specific impulse

(d) With increasing rocket hardware mass fraction

3. A rocket of mass 5000kg is moving with a velocity of 200m/s. If the propulsive efficiency of the rocket is 80% and the propellant flow rate is 10kg/s, the thrust produced would be [0.5]

(a) 4000N (b) 2000N

(c) 1 MN (d) None of the above

4. Choose the incorrect statement about LPRE [0.5]

(a) In a gas pressure feed system pressurized gas is used to supply the propellant from the tank to the chamber

(b) In a pump feed system, propellant is supplied to the combustion chamber at higher pressure using a turbine driven pump

(c) In a pump feed system, high pressure gas is used to supply the propellant from tank to the pump

(d) None of the above

5. Which of the following injector is suitable for injecting gaseous propellant inside combustion chamber in LPRE [0.5]

(a) Coaxial pintle (b) Impinging jet, doublet

(c) Impinging jet, triplet (c) Coaxial swirl

6. In a solid propellant rocket motor with square hollow grain configuration, the maximum thrust would be produced [0.5]

(a) At the beginning of burnout (b) At the end of web burning

(c) At the end of silver burnout (d) both (a) and (b)

7. A rocket of mass 1,000 kg contains 1,500 kg of propellant. The propellant is consumed at a constant rate of 100 kg/s. Find the acceleration of the rocket at lift-off and total incremental speed achieved by the rocket. The specific impulse of the rocket is 1500 N-s/kg. Also take gravity into account. [3]

8. What do you understand by the combustion instability in the rocket engine and how it can affect rocket performance? Explain. Describe the mechanism of high frequency and low frequency instability in the combustion chamber. [3]

9. What do you understand by propellant grain configuration and why it is used? Explain. Discuss the criteria of stable combustion in solid propellant rockets. [3]

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ME F418: Rocket and Spacecraft Propulsion

(**Part-B: Open Book**)

Part B, Total Marks – 28 | 13th May 2022, Total Time: 8 am -11.00am

Instructions:

Part B will be issued after submission of Part A answer sheet.

There are total 6 questions and all the questions are compulsory.

Wherever required draw neat sketch.

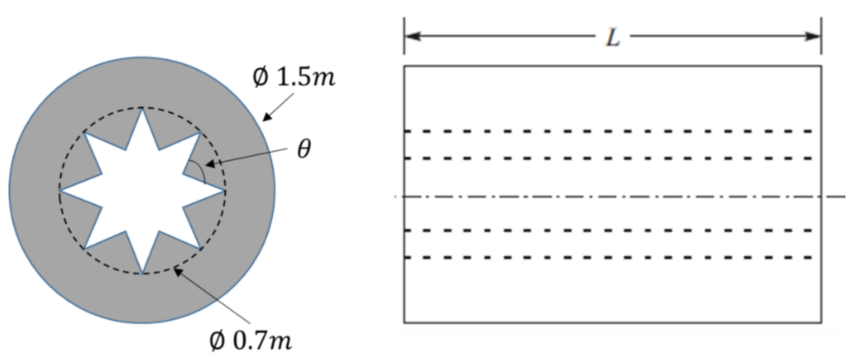
Take suitable assumption, if required, however, it should be stated clearly.

1. Often it is observed to have smoke coming out of the rocket during launch. Explain the underlined reason. In which kind of rocket such smokes are observed? [3]

2. In a liquid propellant rocket, the pressure and temperature of the hot gases are 3300K and 12MPa. The molecular mass of the hot gas is 22kg/kmol and specific heat ratio is 1.4. The C* efficiency due to incomplete vaporization and non-uniform distribution is 0.95 and 0.9, respectively. Calculate the specific impulse (in m/s) of the rocket if the throat area is 0.001 m^2 and thrust produced by the rocket is 13kN. [3]

3. It is desired to expand air from p_0 = 200 kPa and T_0 = 500 K through a throat to an exit Mach number of 2.5 in and convergent-divergent nozzle. If the mass flow rate at choked condition is 3 kg/s, compute (a) the throat diameter, (b) and the length of the divergent section if it is bell shaped with 80% bell contour. Assume isentropic flow with adiabatic constant of 1.4. [4]

4. A rocket uses two solid rocket boosters (SRB) as strap on motors. Each SRB consists of 8 pointed star grain configuration and the diameter of imaginary circle passing through vertices is 0.7m, shown in the figure. The length of the propellant grain is 3m, outer diameter is 1.5m and the length of the each slant edge of star is 0.189m. The angle between slant edge is $\theta = 90°$. The throat diameter of the nozzle used for generating thrust is 100 mm in diameter and the thrust coefficient is 1.2. Calculate the chamber pressure at the beginning of propellant burn in each SRB and the maximum thrust generated by both the SRB. The density of the composite propellant is 1500 kg/m^3 and the characteristic velocity of the propellant is 1700 m/s. The burn rate of the propellant is given in mm/s by the regression law $r = 0.01p^{0.15}$ where the pressure p is expressed in Pa. [5]



5. A bipropellant rocket working on gas generator cycle uses UDMH and N2O4 as fuel and oxidizer, with density of 790 kg/m3 and 1400 kg/m3 respectively. The mean diameter of the propellant droplets injected inside the combustion chamber are 200 micron and their residence time is 0.1s. The chamber pressure and volume is 10 MPa and 0.03m^3. The rate of propellant injection are 5 kg/s and 9.3kg/s for UDMH and N2O4. If the evaporation constant of the UDMH and N2O4 droplet is given as $dD^2/dt = -0.3\,mm^2/s$, and $dD^2/dt = -0.35\,mm^2/s$, respectively. Calculate the mixture ratio of the vaporized propellant and the net C* efficiency assuming the C* efficiency due to non-uniform distribution to be 90%. The variation in C* with mixture ratio can be expressed as C*=1800-100 |(MR -1.86)|, where MR is the mixture ratio. Also estimate the thrust produced by the thrust chamber if the thrust coefficient is 1.3. [6]

6. A spacecraft has to be launched for Earth-Mars mission using Hohman transfer from a parking orbit with an altitude of 324.1 km above the earth surface. Considering the method of patched conics, calculate the (a) escape velocity from the influence of earth gravitational field, (b) incremental speed provided to the spacecraft in the parking orbit such that it will follow the Hohman transfer ellipse in heliocentric phase and (c) the velocity change of the spacecraft caused by the second burn while entering the Mars sphere of influence (planetocentric phase). [7]

	Earth	Mars	Sun
Gravitational Constant μ (m^3/s^2)	3.986×10^{14}	4.297×10^{13}	1.327×10^{20}
Radius, r (m)	6.378×10^{6}	3.393×10^{6}	−
Orbital Radius Around Sun (m)	1.496×10^{11}	3.393×10^{11}	−