Name: **Enrolment No:**	

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2022

Course: Rocket Propulsion — **Semester: VIII**
Program: B.Tech ASE — **Time : 03 hrs.**
Course Code: ASEG 4011P — **Max. Marks: 100**

Instructions: All questions are compulsory
Assume necessary data if not given.

SECTION A
(5Qx4M=20Marks)

S. No.		Marks	CO
Q 1	Explain the need of solid propellants in booster rocket with illustrative example.	**4**	**CO2**
Q 2	Compare the hybrid propellant, liquid propellant and electrical rocket in terms of basic performance parameters.	**4**	**CO3**
Q 3	What are the principal losses that occurred in real nozzle when compared with ideal nozzle?	**4**	**CO3**
Q 4	How Combustion Instability occurs in the rocket engines and explain the methods to control Instabilities?	**4**	**CO4**
Q 5	What are the advantages of electrical propulsion engines (thrusters) over chemical rocket engines?	**4**	**CO1**

SECTION B
(4Qx10M= 40 Marks)

Q 1	Characterize Subsonic, Sonic and Supersonic nozzles based on throat velocity, exit velocity, mach number, pressure ratio and shapes.	**10**	**CO3**
Q 2	A Russian rocket engine (RD-110) consists of four nonmoveable thrust chambers supplied by a single turbopump. The exhaust from the turbine of the turbopump then drives four vernier chamber nozzles (which can be rotated to provide some control of the flight path). Using the information below, determine the thrust, effective exhaust velocity, and mass flow rate of the four vernier thrusters. Individual thrust chambers (vacuum): $F = 73.14$ kN, $c = 3279$ m/sec Overall engine with verniers (vacuum): $F = 297.93$ kN, $c = 3197$ m/sec **OR** Analyze the influence of following parameters on the performance of solid propellant rocket: chamber pressure, propellant exposed surface area, initial grain temp and burning rate	**10**	**CO2**

<table>
<tr><td>Q 3</td><td>The following measurements were made in a sea level test of a solid propellant rocket motor:
<table>
<tr><td>Burn duration</td><td>40 sec</td></tr>
<tr><td>Initial mass before test</td><td>1210kg</td></tr>
<tr><td>Mass of rocket motor after test</td><td>215kg</td></tr>
<tr><td>Average thrust</td><td>62,250 N</td></tr>
<tr><td>Chamber pressure</td><td>7.00 MPa</td></tr>
<tr><td>Nozzle exit pressure</td><td>0.070 MPa</td></tr>
<tr><td>Nozzle throat diameter</td><td>0.0855 m</td></tr>
<tr><td>Nozzle exit diameter</td><td>0.2703 m</td></tr>
</table>
Determine mass flow rate (m.), V_2, C^*, C, and Is at 1000 and 25000 m altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)</td><td>10</td><td>CO1</td></tr>
<tr><td>Q 4</td><td>Analyze the factors influencing injector behavior in the thrust chamber of Liquid Propellant rocket engines.</td><td>10</td><td>CO2</td></tr>
<tr><td colspan="4">SECTION-C
(2Qx20M=40 Marks)</td></tr>
<tr><td>Q 1</td><td>Based on various researches carried in the field on hybrid rocket engines, the researchers propose the idea of three different fuel used in a multi-stage hybrid rocket engine.
Prepare a comparative analysis of rockets hybrid propulsion systems, considering a three stage hybrid rocket engine using one single type of fuel, and a three stage hybrid rocket engine using three different fuels for each stage. You can use the following table for your analysis.
<table>
<tr><th>System</th><th>Propellant</th><th>$a(m^{1+2n}kg^{-n}s^{n-1})$</th><th>n</th><th>$G_0$ ($kg/m^2/s$)</th></tr>
<tr><td>Pure HTPB</td><td>GO_x/HTPB</td><td>$2.85x10^{-5}$</td><td>0.681</td><td>35-280</td></tr>
<tr><td>Paraffin</td><td>GO_x/wax</td><td>$9.1x10^{-5}$</td><td>0.690</td><td>20-120</td></tr>
<tr><td>Paraffin/13%Silbal</td><td>GO_x/fuel</td><td>$9.4x10^{-5}$</td><td>0.766</td><td>150-300</td></tr>
<tr><td>Cryo</td><td>GO_x/CH_4</td><td>$4.14x10^{-5}$</td><td>0.830</td><td>3-30</td></tr>
<tr><td>Pure HTPB</td><td>GO_x/HTPB</td><td>$8.7x10^{-5}$</td><td>0.530</td><td>50-400</td></tr>
<tr><td>HTPB/Al</td><td>GO_x/fuel</td><td>$1.4x10^{-5}$</td><td>0.930</td><td>50-400</td></tr>
<tr><td>HTPB/AP</td><td>GO_x/fuel</td><td>$3.8x10^{-5}$</td><td>0.710</td><td>50-400</td></tr>
<tr><td>HTPB/AL/AP</td><td>GO_x/fuel</td><td>$1.2x10^{-5}$</td><td>0.97</td><td>50-400</td></tr>
</table></td><td>20</td><td>CO4</td></tr>
</table>

	Stage 1	Stage 2	Stage 3
Oxidizer	GOx	LOx	GOx
Fuel	HTPB	HTPB	Paraffin
Oxidizer density [kg/m^3]	1141	1141	1141
Fuel density [kg/m^3]	919	919	940
Oxidizer-Fuel ratio (XO2=1.05)	3.2	3.2	3.61
Specific Impulse [s]	300	300	300
delta V [m/s]	2634	2634	2634
g [m/s^2]	9.8	9.8	9.8
Combustion chamber pressure [N/m^2]	4.5*10^6	4.5*10^6	4.5*10^6
a – regression constant	0.000087	0.000039	0.000091
n – mass flux component	0.53	0.681	0.69
Oxidizer flux [kg/(m^{2}xs)]	2500	2500	250
Burning time [s]	56.81	56.81	56.81
Burning velocity [m/s]	0.006	0.008	0.004
Outer diameter of oxidizer tank [m]	3.187	1.97	1.177
Length of oxidizer tank [m]	3.187	1.97	1.177
Outer diameter of fuel tank [m]	1.027	1.109	0.719
Inner diameter of fuel [m]	0.402	0.196	0.319
Length of fuel [m]	8.747	1.5	0.82
Outer diameter of stage engine [m]	3.193	1.976	1.3
Total length of stage [m]	22.94	11.299	8.3
Load [kg]	20430	4827	1000
Traction [N]	1.2*10^6	2.8*10^5	6.0*10^4
Fuel flow [kg/s]	99.296	23.461	4.428
Oxidizer flow [kg/s]	317.746	75.074	15.985
Fuel mass [kg]	5641	1333	251.555
Oxidizer mass [kg]	18050	4265	908.113

Justify your recommended design based on performance and combustion parameters.

OR

Following data are given for a four stage rocket:

Stages	Mass of propellant (Kg)	Mass of structure (Kg)	Payload mass (Kg)	Jet velocity (m/s)
I (Booster)	10000	1700	50	2250
II	4500	800		2450
III	1900	350		2550
IV	360	50		2850

Determine:

a) Velocity increment for each stages b) total velocity require for initial thrust

c) Propellant mass fraction d) Payload mass fraction e) structural mass fraction at each

stages f) initial acceleration required if time of burning of booster rocket is 50 sec.

Q 2	What is an Anti-satellite targeting missile? Analyze the propulsion systems used in these missions and briefly explain the Kessler syndrome proposed by Donald Kessler for LEO.	**20**	**CO4**