INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Department of Chemical Engineering (S1)

B.Tech. (ChE), Mid Term Examination, Autumn Semester 2024-2025

CHN-323 Computer Applications in Chemical Engineering **Max Marks: 25, Time: 90 mins**

INSTRUCTIONS:

1. Attempt all questions. Answer all parts of a question at single place.
2. Please check all pages of question paper (2 pages) and report the discrepancy, if any.
3. Return the MCQ sheet within first 15 min of the exam.
4. Make suitable assumptions wherever necessary.

Question 1:

A rocket is traveling vertically and expels fuel at a velocity (u) of 2000 m/s at a consumption rate (q) of 2100 kg/s. The initial mass of the rocket (m_0) is 140,000 kg. The rocket starts from the rest at $t = 0$.

(a) Establish that the expression for the velocity of the rocket (in m/s) as a function of time is as follows:

$$v = 2000\ \log_e\left(\frac{14 \times 10^4}{14 \times 10^4 - 2100t}\right) - 9.8t$$

(Hint: you can do force balance on the rocket body; upward force is due to the fuel expulsion that can be expressed as the product of velocity at which the fuel is being expelled and rate at which fuel is expelled (consumed); mass of rocket is changing with time) **[3 marks]**

(b) The speed-reading system shows the following velocities at different times:

Time (s)	0	1	2	3	4	5	6	7	8	9	10
Velocity (m/s)	0	18	38	61	79	97	118	139	204	231	240

Time (s)	11	12	13	14	15	16	17	18	19	20	21
Velocity (m/s)	292	300	314	389	436	453	487	504	531	552	620

Time (s)	22	23	24	25	26	27	28	29	30
Velocity (m/s)	642	675	682	716	803	815	888	901	967

Compare the theoretical velocity calculated from the derived expression and the real velocity measured by speed-reading system by plotting them on a single plot in MATLAB with proper labeling of axes and legends. Calculate root mean square error between the two sets of data by writing a code in MATLAB. **[5 marks]**

(c) Using the velocity data measured by the speed-reading system, calculate the acceleration of the rocket at different times. Write a MATLAB code for this computation. You can use the required finite difference formula form the given below. **[6 marks]**

$O(\Delta x^2)$ centered difference approximations:

$f'(x):\quad \{f(x+\Delta x) - f(x - \Delta x)\}/(2\Delta x)$

$f''(x):\quad \{f(x+\Delta x) - 2f(x) + f(x - \Delta x)\}/\Delta x^2$

$O(\Delta x^2)$ forward difference approximations:

$f'(x):\quad \{-3f(x) + 4f(x+\Delta x) - f(x+2\Delta x)\}/(2\Delta x)$

$f''(x):\quad \{2f(x) - 5f(x+\Delta x) + 4f(x+2\Delta x) - f(x+3\Delta x)\}/\Delta x^3$

$O(\Delta x^2)$ backward difference approximations:

$f'(x):\quad \{3f(x) - 4f(x-\Delta x) + f(x-2\Delta x)\}/(2\Delta x)$

$f''(x):\quad \{2f(x) - 5f(x-\Delta x) + 4f(x-2\Delta x) - f(x-3\Delta x)\}/\Delta x^3$

(d) At Earth's surface, if atmospheric resistance could be disregarded, escape velocity would be about 11.2 km (6.96 miles) per second. Using the given information in above questions, how would you find the time at which the rocket achieves this velocity. Write it in your answer script. Write a MATLAB code to solve the equation (s) desired, using any of the method, except MATLAB's inbuilt solvers. **[6 marks]**