Systems Thinking: Assignment–1

Monsoon 2025 (Instructor: Prof. Spandan Roy)

Release date: 19/08/25 **Due date:** 27/08/25 (11:59 pm)

Instructions & Marking Scheme

Marking Scheme

Question	Marks
Q1	10
Q2	10
Q3	10

Submission Format

- Submit a single `.zip` file named: `Name_RollNo.zip`.
- Inside the zip:
  - `Assignment.pdf` (Solutions for Q1 and Q2)
  - `README.md` (Explanations for Q3: MATLAB usage, functions, variables, and thought process)
  - `q3.m` (MATLAB script for Q3)
  - `plots/` (Folder containing all MATLAB-generated plots in `.png` format)

PDF Content

- Q1: Derivations and explanations
- Q2: State-space matrices, eigenvalues, transfer function derivation
- Q3: Plots from MATLAB with proper labels, titles, and axes (include explanations)

Tools & Integrity

- Use MATLAB for all simulations.
- All plots must be properly labeled (units, axes).
- Work should be original. Any plagiarism will result in zero marks for the question and/or assignment.

References

- Ogata, K. *Modern Control Engineering*.
- MATLAB Documentation: `tf`, `ss`, `lsim`, `ode45`.

Questions

Q1. Application of Transfer Functions (10 marks)

A series RLC circuit has

$$R = 10\ \Omega, \quad L = 0.5\ \text{H}, \quad C = 0.02\ \text{F}.$$

The input voltage is $v_{in}(t)$. The output is the capacitor voltage $v_C(t)$.

1. Derive a single second-order differential equation governing $v_C(t)$ (use KVL and express everything in terms of v_C and its derivatives).
2. Assuming zero initial conditions, use Laplace transforms to find the transfer function

   $$G(s) = \frac{V_C(s)}{V_{in}(s)}.$$

   Write $G(s)$ in simplest rational form.
3. For the input $v_{in}(t) = 5u(t)$ and the given initial conditions $v_C(0) = 1$ V, $i_L(0) = 0.5$ A, find $V_C(s)$ (include the initial-condition terms) and state the inverse Laplace form of $v_C(t)$.
4. From $G(s)$:
   - find zeros and poles (give numerical locations),
   - compute the DC gain $G(0)$
5. Comment briefly on internal/BIBO stability of the system.

Q2. Block Diagram Reduction and Transfer Function (10 marks)

A system has the following block diagram representation:

$$G_1(s) = \frac{10}{s+2}, \quad G_2(s) = \frac{5}{s+1}, \quad H(s) = \frac{1}{s+3}$$

Configuration:

- $G_1(s)$ and $G_2(s)$ are in series.
- The output of $G_2(s)$ is fed back negatively through $H(s)$.
-
```
R(s) --> [ G1(s) ] --> [ G2(s) ] -->----> C(s)
                   |                   |
                   <-------[ H(s) ]<---(-)
```

a) Draw the block diagram based on the description.

b) Reduce the block diagram to find the overall transfer function: $T(s) = \dfrac{C(s)}{R(s)}$.

c) Find the poles of the system and comment on stability.

Q3. MATLAB Simulation (10 marks)

Write a MATLAB script to:

a) Accept as input the coefficients of a second-order linear ODE in the form

$$a_2 \frac{d^2y}{dt^2} + a_1 \frac{dy}{dt} + a_0 y = K\, u(t),$$

where $u(t)$ can be a unit step or sinusoidal input and K be the gain constant.

b) Plot: (i) the input $u(t)$ vs. time, (ii) the output $y(t)$ vs. time.

c) Use both methods:
- `lsim()` with a transfer function object (`tf()`).
- `ode45()` directly on the ODE.

d) Compare and comment on the results from both methods with the plot for the error between them.

e) Example for testing:

$$\frac{d^2y}{dt^2} + 3\frac{dy}{dt} + 2y = u(t), \quad \text{with } u(t) \text{ as the step signal}$$