Midterm Examination 1: Topics and Concepts

Date: February 24, 2026
Coverage: Chapters 1, 2, 3, 4, 5, 6, 7, 8

This midterm covers the foundational principles of Systems Dynamics (SD), focusing on qualitative analysis, modelling perspectives, and the core structural tools: Causal Loop Diagrams (CLDs) and Stock and Flow (S&F) structures, and the resulting basic dynamic behaviours.

Chapter 1: SD Fundamentals & Perspective

- **Policy Resistance:** Understanding why well-intentioned interventions in complex systems often fail or produce counterintuitive side effects.
- **Feedback and Learning:** The distinction between single-loop learning (adjusting decisions based on outcomes) and double-loop learning (revising mental models and system structure).
- **Barriers to Learning:** Dynamic complexity, limited information, time delays, flawed cognitive maps, and attribution error (blaming the person, not the system).
- **SD Worldview:** Understanding systems as tightly coupled, governed by feedback, nonlinear, and history-dependent.

Chapter 2 & 3: The Modelling Process

- **Purpose of Modelling:** Solving a problem (improving performance and policies), not merely modelling an entire system.
- **Modelling Steps (Iterative Process):**
    1. Problem Articulation (defining boundaries, time horizon, and key variables).
    2. Formulating a Dynamic Hypothesis (endogenous explanation of behaviour).
    3. Formulating a Simulation Model.
    4. Testing (assessing suitability and robustness).
    5. Policy Design and Evaluation.
- **Reference Modes:** Generating and interpreting historical and projected patterns of behaviour over time (e.g., exponential growth, oscillations).
- **Endogenous vs. Exogenous:** The crucial importance of making factors responsible for the problem dynamics internal (endogenous) to the model boundary.

Chapter 4: Structure and Behaviour of Dynamic Systems

- **The Link between Structure and Behaviour:** The principle that a system's behaviour arises entirely from its internal feedback structure.
- **Fundamental Modes:**
    - **Exponential Growth:** Generated by positive (self-reinforcing) feedback loops (R).
    - **Goal Seeking:** Generated by negative (self-correcting/balancing) feedback loops (B).
    - **Oscillation:** Generated by negative feedback loops containing significant time delays.
- **Complex Modes:** S-Shaped Growth, Overshoot and Collapse (arising from non-linear interactions of fundamental modes).

Chapter 5: Causal Loop Diagrams (CLDs)

- **Notation:** Representing variables, causal links (arrows), and polarity signs (+ and -).
- **Polarity Determination:** The rules for assigning link polarity (ceteris paribus assumption) and loop polarity (counting negative links).
- **Causation vs. Correlation:** Ensuring links represent genuine causal pathways.
- **CLD Guidelines:** Importance of naming loops, indicating delays, and avoiding diagrams that are too large or complex for effective communication.

Chapter 6: Stocks and Flows (S&F)

- **Conceptual Definition:** Stocks (accumulations, inertia, memory) decouple inflow and outflow rates, generating disequilibrium. Flows (rates) change the size of the stock.
- **S&F Notation:** Using rectangles (stocks), thick arrows/pipes (flows), valves (rates), and clouds (sources/sinks).
- **Dimensional Consistency:** Understanding how units confirm whether a variable is a stock (units) or a flow (units/time).
- **The Snapshot Test:** Identifying true stocks in a system.
- **Conservation of Material:** Understanding which flows are conserved (material/people) versus non-conserved (information).
- **Model Boundaries (Challenging the Clouds):** Recognizing that external clouds imply infinite source/sink capacity and zero feedback from boundary components.

Chapter 7: Dynamics of Stocks and Flows

- **Integration and Differentiation:** Understanding the relationship between stocks (integration of net flows) and flows (differentiation of stocks).
- **Graphical Integration:** The ability to sketch a stock's behaviour given the net flow rate over time (Area under the curve = Change in Stock).
- **Graphical Differentiation:** The ability to sketch the net flow rate given the stock's trajectory (Slope of the curve = Net Flow Rate).
- **Delays:** Understanding that all delays necessarily contain at least one stock (e.g., material in transit, perceived conditions).

Chapter 8: Closing the Loop: Dynamics of Simple Structures (First-Order Systems)

- **Order of System:** Defined by the number of independent stocks.
- **Linear Positive Feedback:** Generating pure exponential growth (e.g., interest compounding). Calculation of the **Doubling Time** (Rule of 70).
- **Linear Negative Feedback:** Generating pure exponential decay (goal seeking). Calculation of the **Half-Life** or **Adjustment Time**.
- **Phase Plots (First-Order):** Analyzing the plot of Net Inflow Rate vs. Stock to determine equilibrium points (where rate = 0) and their stability (slope).
- **Nonlinear First-Order Systems (S-Shaped Growth):** The mechanism by which loop dominance shifts from positive to negative feedback as the stock approaches carrying capacity, causing the growth rate to slow to zero.
- **Oscillation Constraint:** Understanding why first-order systems cannot oscillate (oscillation requires at least two independent stocks, often represented by time delays).