Guided Study Program in System Dynamics

System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management

Assignment #5

Reading Assignment:

Please read the following:

- *Principles of Systems*,[2] by Jay W. Forrester, Sections 2.1, 2.2, 2.4

Then refer to Road Maps 3: A Guide to Learning System Dynamics (D-4503-4) and read the following papers from Road Maps 3:

- Graphical Integration Exercises Part 2: Ramp Functions (D-4571)
- Beginner Modeling Exercises Section 2: Mental Simulation of Positive Feedback (D-4487)
- Beginner Modeling Exercises Section 3: Mental Simulation of Negative Feedback (D-4536)

[2] Forrester, Jay W., 1968. *Principles of Systems*, (2nd ed.). Portland, Oregon: Productivity Press. 391 pp.

Exercises:

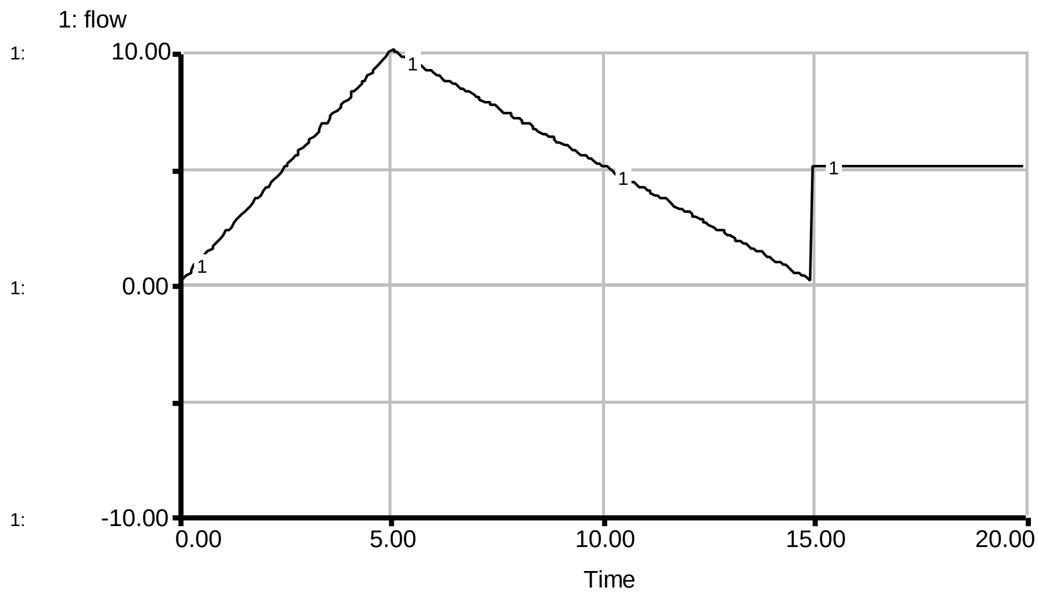
1. Principles of Systems

Please read sections 2.1, 2.2, and 2.4 in *Principles of Systems* (we will return to sections 2.3 and 2.5 in later assignments) and do the workbook exercises for these sections (located at the end of the book). You should understand all the material in these sections; please let us know if you have any questions. You do not need to submit anything for this reading assignment.

2. Graphical Integration Exercises Part 2: Ramp Functions

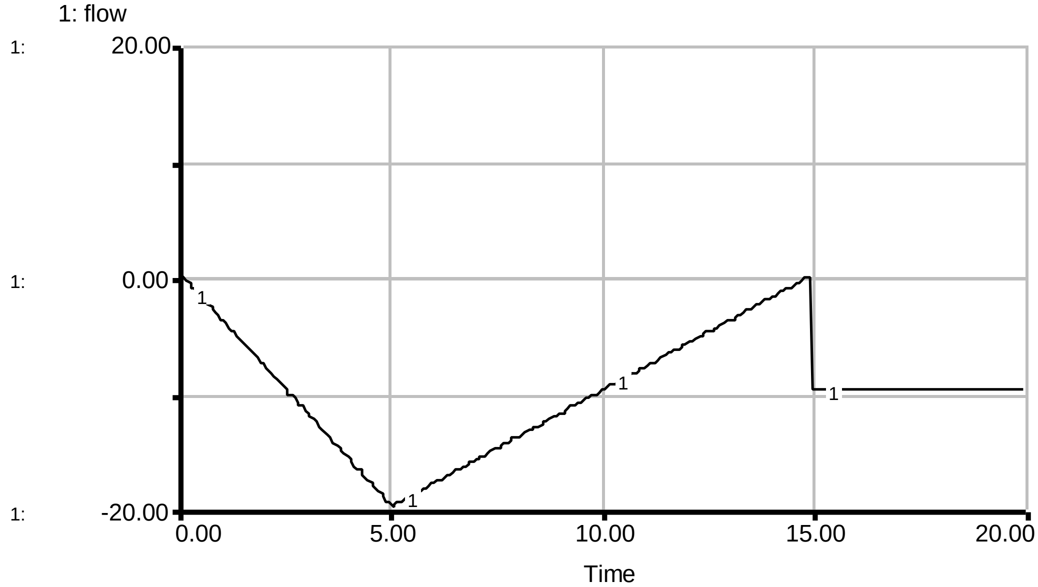
A. Using the skills you acquired in *Graphical Integration Exercises Part Two*, graphically integrate the following flows. Use a graphics application to create the graphs of the stock behaviors, and then paste the graphs into your assignment solutions document.

1. Assume that the initial value of the stock is –50.



At time =0, the flow is at 0. From time = 0 to time = 5, the flow increases linearly with slope +2. From time = 5 to time = 15, the flow remains positive but decreases linearly with slope –1. The flow then steps up to +5 at time = 15 and remains constant at +5 until time = 20.

2. Assume that the initial value of the stock is 100.



The flow again starts at 0. From time = 0 to time = 5, the flow decreases linearly with slope –4. From time = 5 to time = 15, the flow remains negative but increases linearly with slope +2. At time = 15, the flow steps down to –10 and remains constant at –10 until time = 20.

B. Although graphical integration may just seem as a useless exercise in arithmetic, an intuitive understanding of the process is often useful when trying to understand the behavior of a system. Using the insights from the two Graphical Integration Exercises papers that you have read so far, fill in the following table by trying to generalize what type of stock behavior results from various types of flow behaviors.

Sign of Flow	**Value of Flow**	**Stock Behavior**
zero flow	zero	
positive	constant	
	increasing	
	decreasing	
negative	constant	
	increasing	
	decreasing	

How does the sign of the flow determine the stock behavior? How about the value of the flow? What is the role of the initial value of the stock?

3. Beginner Modeling Exercises Section 2: Mental Simulation of Positive Feedback

A. As required in the Exploration exercise #1, give three simple examples of positive feedback systems (please try to think of systems that have not been mentioned in the readings so far). For each example, provide a short verbal description (one or two sentences) of the positive feedback loop.

B. Pick one of the systems you described in part A. and build a model of the system using Vensim PLE. Choose the initial value of the stock and the value of the growth fraction, formulate the equations for the model, and simulate the model. What type of behavior does the model generate? In your assignment solutions document, please include the model diagram, documented equations, and a graph of the model behavior.

C. What is the doubling time of the system? Explain intuitively the difference between the growth fraction and the doubling time of a system. Feel free to support your answer by deriving an equation, but we are looking for a verbal explanation here.

D. Can a positive feedback system be in equilibrium? Why or why not? If yes, describe the various situations that might lead to equilibrium.

E. As mentioned in *Beginner Modeling Exercises Section 2*, growth of a positive feedback system cannot continue forever. Describe some factors that might limit the growth of the system you modeled in part B.

4. Beginner Modeling Exercises Section 3: Mental Simulation of Negative Feedback

A. As required in the Exploration exercise #1, give three simple examples of negative feedback systems of the same type as the rainfall system (please try to think of systems that have not been mentioned in the readings so far). For each example, provide a short description (one or two sentences) of the negative feedback loop. Then give three examples of negative feedback systems of the same type as the solvent absorption system, and, in one or two sentences, describe the negative feedback loop for each of them. What are the differences and similarities between the two types of negative feedback systems?

B. For each of the two types of negative feedback systems, do the following: pick one of the systems you described in part A. and build a model of the system using Vensim PLE. Choose the initial value of the stock and the values of any other variables in the model, formulate the equations for the model, and simulate the model. What type of behavior does the model generate? Compare the behaviors generated by the two models.

In your assignment solutions document, please include the model diagram, documented equations, and a graph of the model behavior for both models.

C. Calculate the half-lives for both systems. Explain intuitively the difference between the decay or growth fraction and the half-life of a system. Feel free to support your answer by deriving an equation, but we are again looking for a verbal explanation here.