Systems Thinking Module: Summative Assessment Questions

These questions can be incorporated into homework, quizzes, or exams. Instructors may choose which questions are more appealing and relevant for their specific class. Questions for homework, quizzes, or exams. These questions are listed as options, and are not intended to all be used on one quiz or exam. There are intentionally some redundancies.

Unit 1

1. Think of what it means to approach a topic from a reductionist perspective versus a systems thinking perspective. Classify the following concepts as advantages of reductionist thinking or systems thinking:
   (a) Topics may be easier to digest as smaller pieces - Reductionist
   (b) May be helpful in laying the foundation of a new topic because of the focus on simpler components - Reductionist
   (c) Naturally collaborative as connections between multiple disciplines are common Systems
   (d) May lead to an easier sense of learner "accomplishment" as individual sub-topics are mastered - Reductionist
   (e) Provides a more realistic perspective on how science is done by considering multiple inputs and outputs - Systems
   (f) May work better for a "solo" project - Reductionist
   (g) Better suited for tackling complex, big-picture problems - Systems
   (h) Gives a "fuller" understanding of how phenomena work - Systems

2. We live in complex environments that contain many different but complementary systems interacting with each other. Describe one environment you see that can be represented as a system. List its components. Why might a systems-thinking approach be advantageous for this environment?

   There are obviously many examples that can be listed here. A complete answer will be something with three or more interconnected components. Example:

   A fish tank can be thought of as a system. Components include water circulation, temperature, food, pH, algae growth, fish compatibility, and salt level. A systems-thinking approach can be useful because the health of the fish in the tank is influenced by many of these factors simultaneously, and some of the factors are related (such as temperature and algae growth).

3. Do you think you would prefer to learn new material through a reductionist approach or a systems-thinking approach? Explain your reasoning.

   Examples: I believe a reductionist approach would be easier for learning new material. Systems thinking seems more complicated.

   I think Systems Thinking provides a more realistic way of approaching science, so I would prefer learning that way.

4) Say that you have a vegetable garden, and the productivity of it is much lower this year than it was last year. Describe a reductionist approach to figuring out why productivity decreased? Describe a systems thinking approach to figuring out why productivity decreased?

   Reductionist: I will try to "fix" one thing at a time, such as how much I water, what time of day I water, what kind of fertilizer I use, how I control pests, etc. Then I will see which change will improve my garden.

   Systems: I will determine which factors are interrelated and which factors I can change to make a difference. For example, maybe I need to change both fertilizer and watering because those components affect each other and cannot be considered independently.

Unit 2

1) The United Nations Sustainable Development Goals set out an ambitious agenda to: (choose the best answer)
   (a) Reach an international agreement to stop climate change
   (b) Reduce the rate of extinction of birds
   (c) Meet the basic needs of all the world's people while preserving the planet
   (d) Reduce the proliferation of nuclear weapons

For question 2, could provide students with a list of UNSDGs, unless the recall aspect of the question is desired.

2) List two of the 17 United Nations Sustainable Development Goals and for each of the two goals,
   (a) Identify four components of the system that goal is part of
   (b) Write two sentences that explain how chemistry (or materials, products, or processes that require chemistry) could help achieve the goal.

This assessment question is drawn from the activity on UNSGDs and connections to chemistry. Though students would not be expected to write as detailed of an answer on an exam (working on their own) as in a group discussion, the 2.1 UNSDG instructor notes discussion of system components for the six highlighted UNSGDs and how chemistry connects to them is guidance on appropriate responses.

For questions 3-6, students would be provided with a list of the UNSDGs.

3) Developing better materials and processes for the desalination (removing salt) of seawater is an active area of chemistry research. List two UNSDGs whose attainment would be aided by better methods of desalination. Briefly explain your choices.
   - Clean water and sanitation- desalination would increase the supply of drinking water
   - Zero hunger- agriculture relies on sources of suitable water
   - Responsible production and consumption- decrease waste association with spent filters
   - Climate action- water purification is energy intensive, and as such results in GHG emissions

4) Developing plastics that can either fully biodegrade or can be more efficiently and effectively recycled is an active area of chemistry research. List two UNSDGs whose attainment would be aided by these improvements in plastics. Briefly explain your choices.
   - Responsible production and consumption- decrease the amount of waste generated from plastics
   - Life below water- reduce the quantity of plastics in oceans, lakes, and rivers

5) Developing rechargeable batteries that last longer, are cheaper, and are made from more Earth-abundant metals is an active area of chemistry research. List two UNSDGs whose attainment would be aided by these improvements in batteries. Briefly explain your choices.
   - Affordable and clean energy- batteries are essential for using intermittent energy sources (like solar and wind)
   - Sustainable cities and communities- batteries play an important role in decreasing the energy usage and pollution emissions associated with transportation
   - Responsible production and consumption- reduce use of less abundant elements, or use them in a way that they can be recovered
   - Climate action- better and more widely available battery technology would foster the greater adoption of solar and wind energy and of electric cars and trucks

6) Developing methods of controlling insect pests that do not harm non-target species is an active area of chemistry research. List two UNSDGs whose attainment would be aided by this improvement in pesticides. Briefly explain your choices.
   - Zero hunger- losses of crops to pests affects agricultural productivity and the food supply
   - Good health and well-being- reduce deaths and illnesses due to exposure to pesticides; non-target species includes people
   - Clean water and sanitation- the quality of potential drinking water can be affected by the presence of pesticides
   - Life below water- decrease pollution in marine environments

7) Green chemistry seeks to replace chemicals that are hazardous to human health and the environment with safer options. List two UNSDGs whose attainment would be aided by the widespread use of safer chemicals. Briefly explain your choices.
   - Good health and well-being- reduce deaths and illnesses due to exposure to hazardous chemicals and pollutants
   - Clean water and sanitation- the quality of potential drinking water can be affected by chemical pollution
   - Life below water- decrease pollution in marine environments

Questions 8 and 9 are only appropriate if concept maps have been introduced in the course.

8) Draw a concept map for what you learned in this course in the past two weeks and include one United Nations Sustainable Development Goal in the map. In your concept map, make at least two connections between the Goal included and chemistry concepts.

The content included in the concept map will vary depending on when in the course this question is asked. A key aspect of the question is connecting recent content in the course to a UNSDG

9) Draw a concept map for what you have learned in this course in the past two weeks and include at least two concepts from other courses you are taking this semester or have taken recently. In your concept make at least two connections from each of the concepts from other courses to the chemistry concepts.

   Responses to this question will vary greatly, depending both on when in the semester it is asked, and what other courses the student is taking.

Unit 3

1) Which size scale might a physicist/chemist/biochemist/biologist/geoscientist/policy maker be focused on?
   A biologist might be focused on the scale of an organism, anywhere from 1 cm to 10 m.

2) Why is it important to choose an appropriate size scale? What are some risks with choosing a system that's too big or too small for a particular problem?

   Choosing a scale that's too big might cause one to miss important small-scale properties. Choosing a scale that's too small might make it difficult to predict or observe large scale outcomes.

3) How do entities on a smaller scale affect entities on a larger scale? For example, how might proteins affect the function of a whole cell? Further, how might cell function affect a whole organism?
   Smaller pieces of a cell, like proteins, work together to keep the cell healthy and serving its overall function. For example, proteins might serve as waste removal or repair of a cell. The smaller scale structures lead to the larger scale properties.

4) Which of the following are reasons for defining proper system boundaries (more than one may apply)?
   a. Saves time / effort
   b. Compartmentalizes complex problems
   c. Inspires others to address the problem in question
   d. Adds complexity to a problem

5) Imagine you are a university financial aid officer. Pick three components that are important for your job function. In other words, which components may be within the boundaries of a system addressing a problem that may occur as part of your job? Give a brief (1-2 sentence) justification for your answer.
   a. Student discipline
   b. Availability of scholarships
   c. Cafeteria menu
   d. Family income
   e. Loan applications
   f. Sports team's record

A financial aid officer would focus on family income, loan applications, and availability of scholarships. They would bring a specific expertise for these elements, and it would help them function in their job to help students acquire financial aid.

6. Imagine you work in the chemical industry. Your company has developed a new material called CHEMiracle with a set of desirable properties. It is now your job to scale up manufacturing CHEMiracle to an industrial scale (dozens or hundreds of kilograms at a time). Which of the following components should you focus on to address this problem? Justify your choices. In your response you should include at least one component and exclude at least one component.

   Components: Cost of starting material, side products, negotiating purchases of CHEMiracle, temperature of reactor, waste disposal, marketing of CHEMiracle, availability of equipment, exploring new applications of CHEMiracle

   To address the problem of scaling up manufacture of CHEMiracle, I would focus on the following components: cost of precursors, side products, temperature of reactor, waste disposal, and availability of equipment. These are components directly involved in the manufacturing process, and management of these components could impact the scaling-up process. Other elements, such as negotiating purchases, marketing, and exploring new applications would be better handled by other individuals or entities since they do not directly impact scaling up.

7. Imagine a local chemical company accidentally released a significant amount of toxic material into the environment. Select one of the three roles responsible with dealing with aspects of the incident. After selecting a role, pick at least three responsibilities appropriate to address for someone in that role and at least one responsibility that does not fall under the role. Justify your choices.

   Roles: Government regulator, public relations specialist, chemical safety officer

   Responsibilities: Safety of workers, safety of public, communicating information to the public, reputation of company, financial impact on company, revising company safety practices, stock prices, sales of company products

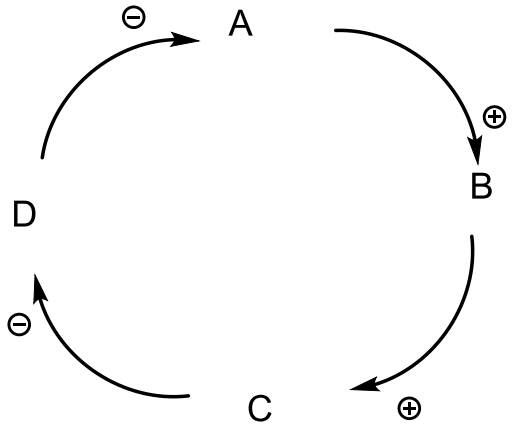
   Role – government regulator. Included responsibilities – safety of workers, safety of public, communicating information to the public. Excluded responsibility – Stock prices. A government regulator is a public servant who would be concerned with the public, including safety and communication. They do not work for the company, and therefore do not care about stock prices.

Unit 4
True or false

1) If a causal loop diagram has an odd number of negative polarity linkers, the loop is reinforcing. F; It is balancing

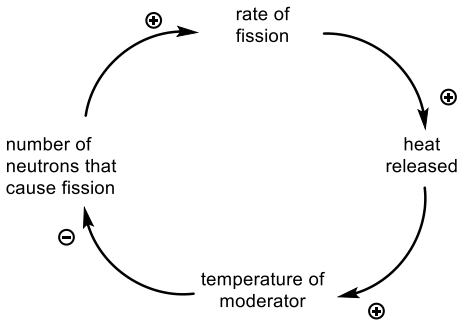
2) If a causal loop diagram has an odd number of positive polarity linkers, the loop is balancing. F; The number of positive polarity linkers does not affect if the loop is balancing or reinforcing.
3) A positive polarity linker indicates that the component at the head of the arrow is increasing. F; A positive polarity linker indicates that the direction of change is the same for the element at the base of the arrow and at the head of the arrow.
4) A positive polarity linker indicates that the component at the base of the arrow and the component at the head of the arrow are changing in the same direction. T
5) A negative polarity linker indicates that the component at the head of the arrow is decreasing. F; A negative polarity linker indicates that component at the base of the arrow and the component at the head of the arrow are changing in the opposite direction
6) A negative polarity linker indicates that the component at the base of the arrow and the component at the head of the arrow are changing in the opposite direction. T

7) Is this a reinforcing or balancing feedback loop? Explain.



It is reinforcing. If A increases, B will increase, which will cause C to increase, which will cause D to decrease, which will cause A to increase.

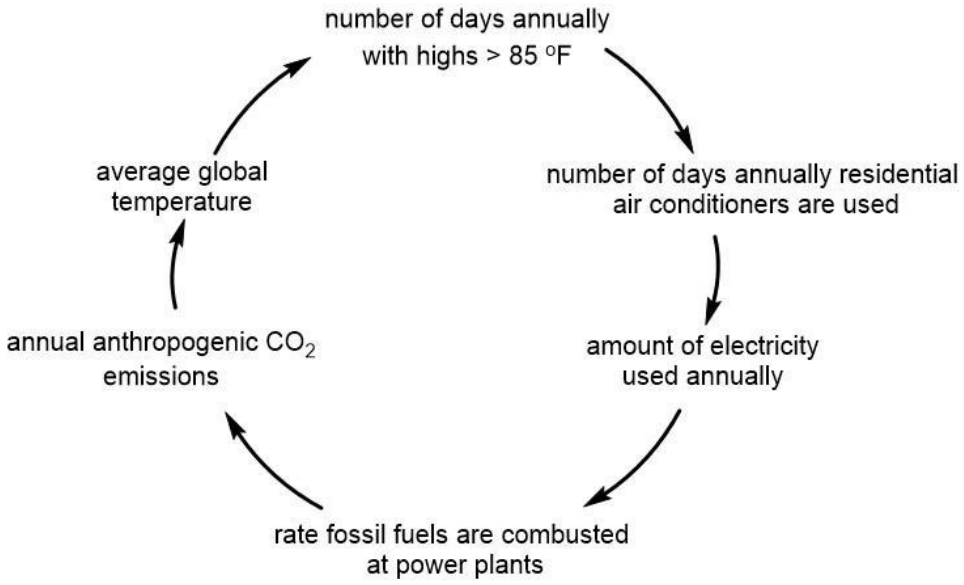
8) Is this a reinforcing or balancing feedback loop? Explain your reasoning.



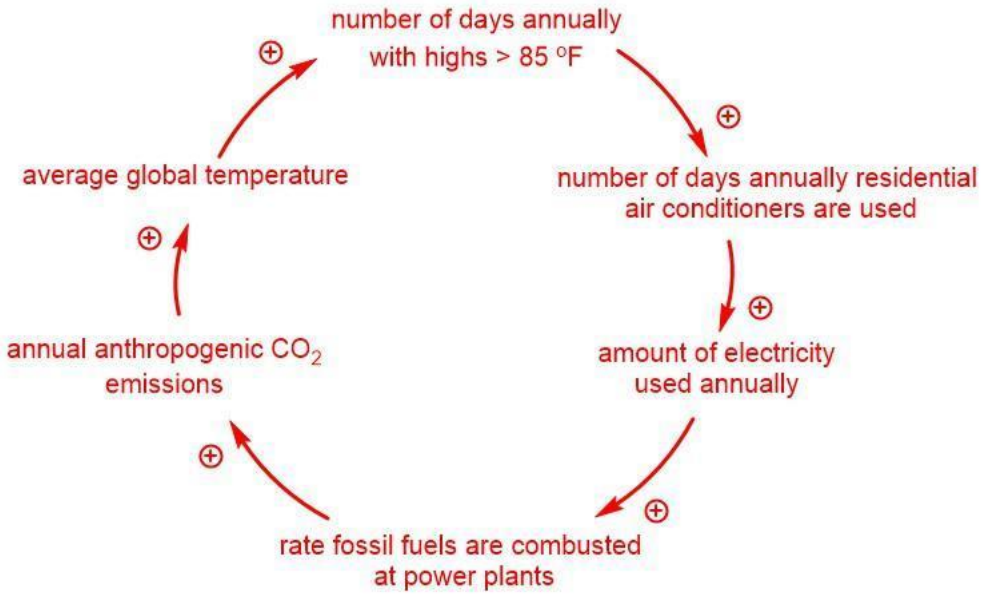
This is a balancing loop. There is one negative polarity linker. Walking through the loop, if the rate of fission increases more heat is released (+); if more heat is released the

temperature of the moderator increases (+); if the temperature of the moderator increases the number of neutrons present that can cause fission decreases (-); if the number of neutrons available to induce fission decreases the rate of fission will decrease. The change the second time through the loop is in the opposite direction of the change the first time through the loop. Note that would reach the same conclusion if started with a perturbation of decreasing the rate of fission. Note also that students don't need to know anything about fission reactors to answer the question; just need to be able to read a CLD.

9. Indicate the polarities (plus or minus) for each of the linkers. Explain your reasoning for each. Indicate if this loop is balancing or reinforcing.



If there are more hot days, air conditioners get used on more days (+). If air conditioners are run for more days, electricity usage increases (+). If electricity usage increases, more of fossil fuels will be combusted at power plants (+). Note- not all power plants burn fossil fuels—there is hydropower, and nuclear fission, and biofuels, and of course some people have their own solar panels. Currently in the U.S., 57% of electricity is generated through the use of fossil fuels (https://www.eia.gov/totalenergy/data/monthly/pdf/flow/total_energy_2020.pdf). More fossil fuel combustion will release more CO_2 (+). Since CO_2 is greenhouse gas more CO_2 will increase the average global temperature (+), which will result in more hot days (+). All the polarities are positive, which results in a reinforcing feedback loop.



Unit 5

1. Label each of the following as a stock or a flow.
   Concentration of CO_2 in the atmosphere stock
   Amount of methane in the Marcellus Shale (a rock formation in the Eastern United States) stock
   Annual increase in atmospheric CO_2 concentration flow
   Temperature of a reaction flask stock
   Number of moles of reactant in a flask stock
   Rate of a chemical reaction flow
   Total volume of solvents in a chemistry building stock
   Number of bottles of waste that the waste management company removes from a chemistry building each week flow

2. Which of these are appropriate units for a flow? (select all that are)
   Moles per L per second
   Grams
   Dollars
   People per minute
   Megajoule per hour
   Kilowatt (units are kJ/s)
   Kilowatt hour (units are hour*kJ/s)

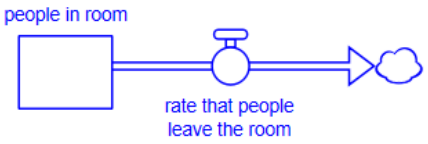
3. Explain the difference between a stock flow diagram and a systems dynamics model.
   A stock flow diagram is a representation of a system, just like a causal loop diagram is a representation of a system. A stock flow diagram indicates components of a system and how materials flow between those components. A systems dynamics model is a computer-

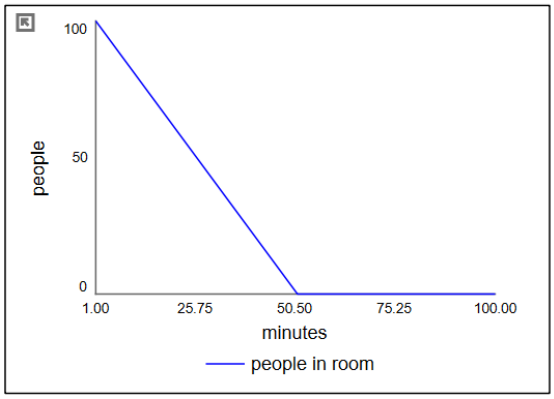
based simulation model, which uses the equations defined for the flows to calculate how the quantities in stocks change over time.

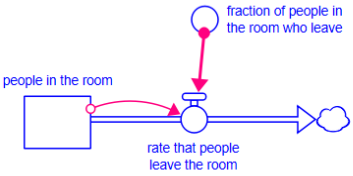
4. A stock flow diagram can be the basis for a systems dynamics model. The output from a systems dynamics model is a behavior over time plot.

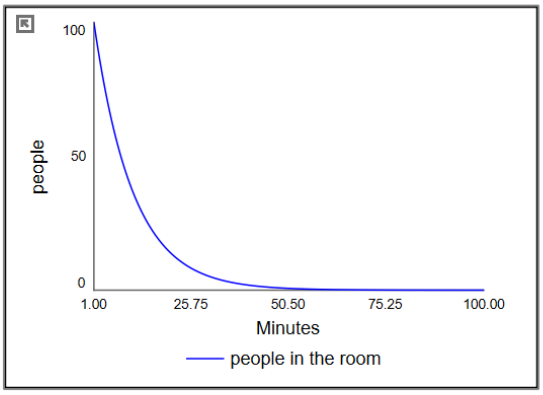
   Two model structures (A and B) and two output plots (1 and 2) are shown below.

   a. Identify the stocks in these models. People in the room
   b. Identify the flows in these models. Rate that people leave the room
   c. Do these models indicate where the people who leave the room go? No, the cloud icon indicates that where they go is outside of the system boundary
   d. In which model does the rate that people leave the room depend on the number of people in the room? Explain. Model B. There is an information connector between the number of people in the room and the flow rate. This connector indicates that the flow rate will depend on the number of people in the room.
   e. Which output plot resulted from which model? Explain.
      Model A produces behavior over time plot 2, and model B produces behavior over time plot 1. In model A, the rate that people leave the room is not dependent on anything- there are no pink connector arrows attached to it. This means that the rate that people leave the room is constant, and will produce a linear plot of people in the room vs. time. In model B, the rate that people leave the room depends on the fraction of people in the room who leave (a constant) and the number of people in the room. Since the number of people in the room is decreasing the rate that they leave the room will also decrease.

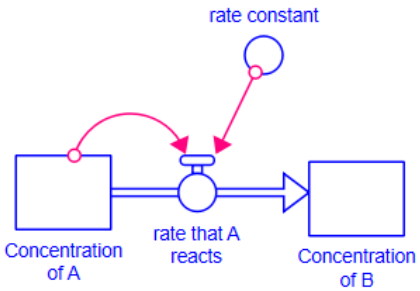


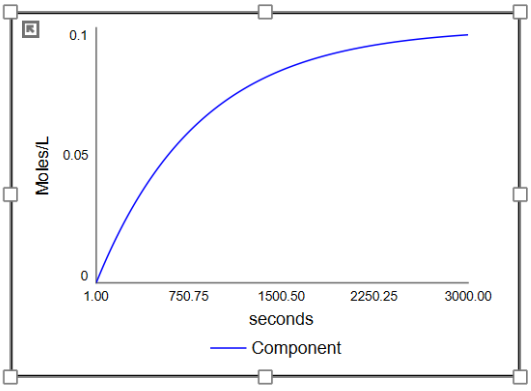






5. This is a stock flow diagram of a chemical reaction and a behavior over time plot for a systems dynamics model based on this diagram.





What component of the stock-flow diagram is being plotted?
(a) Concentration of A
(b) Rate that A reacts
(c) Rate constant
(d) Concentration of B

The concentration of A and the rate that A reacts will decrease over time. The rate constant will not change over time. The concentration of B will increase over time.