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Activity Sheet 14: Sensitive Systems and Computer Modeling

14.1 Sensitivity of Systems to Initial Conditions

1) Predictable and unpredictable systems

Your instructor will demonstrate a simple pendulum, starting its motion several times.

- a) Is it possible to predict the motion of this pendulum each time? _____
- b) What set of laws govern the motion of the pendulum?

- c) Your instructor will demonstrate a modified pendulum that includes a spring.
Does this pendulum also follow Newton's Laws? _____
Can you predict the motion of this pendulum? _____
- d) When the second pendulum is repeatedly set in motion with as close to identical conditions as possible, does this pendulum behave the same each time? _____
How does the spring change the character of the pendulum?

2) Deterministic systems

As we have seen, both predictable and unpredictable systems follow Newton's Laws.

- a) What is the term for a system for which we know the laws governing the system's behavior? _____
- b) What is the relationship between successive events in a deterministic system?

- c) Are there any systems in nature that are not deterministic?

3) Sensitive and non-sensitive systems and initial conditions

Next, we examine the difference between predictable and unpredictable systems.

- a) Place the ice cream cone upside down. Tilt the cone slightly to the right side and release it. What happens?

- b) Is the behavior of the cone predictable? _____

c) Change the initial conditions by tilting the cone to the left or toward you or away from you and then release the cone. Is the final position of the cone the same in each case?

d) Is the final position of the cone sensitive to your choice of initial conditions?

e) Now turn the cone over and try to balance it on its tip. When you release the cone, can you predict in which direction it will fall? _____

Does the cone on its tip represent a system that is sensitive or not sensitive to the initial conditions?

f) What is the difference in the initial conditions that predict which direction the cone will fall?

g) What is the difference between a system that is predictable and one that is not predictable?

h) Group Discussion Question: In the examples seen thus far (the carts, the pendulums, and the ice cream cone), what laws govern the motion of the objects? _____

What information do you need in addition to these laws to predict the motion of the objects?

4) **More examples of sensitive and non-sensitive systems**

Your instructor will demonstrate two types of balls.

a) Which ball represents a non-sensitive system? _____

b) Which ball represents a sensitive system? _____

c) Which ball represents a deterministic system? _____

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- d) Your instructor will demonstrate more systems. For each system, indicate the factors determining the initial conditions. Is each system sensitive or not sensitive to the choice of initial conditions?

Example	Initial Conditions	Sensitive or Non-sensitive
Double pendulum		
Magnetic spinner		
Illumitron ball		
Balloons		

- e) Group Discussion Question: Give examples of objects in the room for which you can predict the object's behavior.

14.2 How to Turn Sensitivity into Probability

5) Probability with Dice

- a) Rolling dice has unpredictable results. When you roll a single die, what are the possible outcomes?
- b) What is the probability of each outcome per roll?
- c) Roll one die 12 times. Make a histogram in the grid below by darkening one square that corresponds to the number on the die for each roll. At the end, you will have 12 blackened squares.

10						
9						
8						
7						
6						
5						
4						
3						
2						
1						
	1	2	3	4	5	6

Number on die

- d) What histogram would you expect based on the probability from part 6.b)?
- e) What determines the outcome of each roll?
- f) Is the system of rolling dice a sensitive system?
- g) Why doesn't your histogram match the probability expectations?
- h) Try adjusting the initial conditions of rolling the die so that you get the same result with each roll. Were you successful? Why or why not?

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14.3 Computer Simulations

6) Using Computer Simulations

- a) Why are computer simulations used? Describe situations for which simulations are useful.

- b) What are some limitations and disadvantages of computer simulations?

14.4 Balance of the Planet

Your instructor will explain this computer simulation.

7) Energy Sources

- a) We will test whether Balance of the Planet is a sensitive computer simulation by comparing the results of different initial conditions. On the Policy screen, set the taxes and subsidies to **encourage** the use of fossil fuels – coal, oil, and natural gas. Do not change other taxation and subsidy categories. Execute your policies and play the game through 2005 by adjusting the taxes for each 5-year period. Record your scores from the Results screen onto the score sheet. Then exit this game.
- b) Start a new game in which you **discourage** the use of fossil fuels through taxes and subsidies. Play the game through 2005 and record your scores. Exit this game.
- c) Compare the results of these two games.
 - 1) When you encourage the use of fossil fuels, which point categories improve?

Which point categories worsen?

- 2) When you discourage the use of fossil fuels, which point categories improve?

Which point categories worsen?

- d) Based on the results of these two games, do you think this computer simulation is sensitive to initial conditions? Why or why not?

8) World Food Supply Providing adequate nutrition for people and reducing starvation is a difficult problem to solve in this simulation.

- a) Which tax categories would you increase and which would you decrease to reduce starvation?
- b) Why would increasing the beef tax reduce starvation?
- c) Which items would you subsidize to reduce starvation?
- d) Using your strategies to reduce starvation, play a game to the year 2035. Record the results on the score sheet.
- e) Which point categories improved as a result of your strategies? Which categories worsened?

9) Other Environmental and Societal Issues

- a) Check the Policy screen and the Results screen for other environmental or societal issues you wish to address with taxes or subsidies. When you have adjusted the tax and subsidy rates, play another game and record your results on the score sheet.
- b) What is the final score from your best game? _____

10) Balance of the Planet as a model of the Earth

Balance of the Planet uses 150 variables to simulate the Earth's environment. You are able to choose the initial conditions of many of these variables for each five-year period.

- a) How does a simulation like Balance of the Planet produce the results you see every 5 years?
- b) How could a simulation program such as balance of the Planet be used to develop a series of probable outcomes?
- c) Group Discussion Question: In your opinion, is the Earth's environment a sensitive system in which changes to one variable may produce large effects in other variables?