

## Module 5C

### Advanced Systems Modeling

### Looking Under the Hood with Vensim

In *the Introduction to Systems Modeling* workshop, we looked at various behaviors that a systems model could generate and the real-world problems they might represent. To summarize, we looked at:

- Linear Growth and Decline
  - Speed of a car with constant acceleration
  - Savings generated by a constant weekly allowance, no spending, no interest
  - Volume of water in a tub as water enters at a constant rate
- Quadratic Motion
  - The position of a baseball as it is thrown from an outfielder to first base
  - The position of an object as it falls from the top of a building to the ground
  - The distance traveled by a car as it accelerates at a constant rate from rest
- Exponential Growth and Decay
  - Amount of radioactive material as it decays over time
  - Savings remaining if a fixed percentage of the savings is spent weekly
  - Temperature of a hot cup of coffee as it cools to room temperature
- Bounded Growth
  - Spread of a forest fire as measured by the number of burnt trees as time passes
  - Spread of a disease as measured by the number of affected people as time passes
- Periodic Behavior
  - Predator and prey populations as they interact over a period of years
  - Glucose and insulin levels as they fluctuate during the day
  - Motion of a frictionless vertical spring

Now we want to:

1. Identify hypotheses that could be tested with systems models of these problems.
2. See if the available model is adequate to run an experiment.
3. Understand the math behind the model.
4. Make selected modifications to tailor the model to your needs.

We'll do Projectile Motion together.

Projectile Motion

- Open the model and run it.
- What does the graph show?
  - The flight of the object when thrown at a launch angle at an initial velocity
- Describe the labels on the x and y axes.

- X is the horizontal position of the object, Y is the vertical position
- What experiment could you run with this model?
  - You could see how the launch angle and the initial velocity change the flight of the object
- Do a “simulate with change” run.
- Notice the sliders – what are the independent variables?
  - Initial velocity, launch angle, acceleration due to gravity
- Design an experiment that students could run using this model.
  - Holding the launch angle constant, change the initial velocity to see the effect on the flight of the object.
  - Holding the initial velocity constant, change the launch angle to see the effect on the flight of the object.
  - Change the value of gravity to simulate projectile motion on another planet
- What would you like to modify on the model?
  - Max y and Max x on the graph – use the Control Panel
  - Change Vertical Speed to Vertical Velocity – use  $Y = x^2$
- What is the math behind the model?
  - Use the  $Y = x^2$  button
  - Note that the vertical position is affected by gravity so two rates of change are needed – acceleration due to gravity is the rate of change of vertical velocity; but vertical velocity is also the rate of change of vertical position.
  - Note that trigonometry is needed to calculate the initial vertical and horizontal velocities
- How do you add units?
  - Use the  $Y = x^2$  button
- What are the model settings?
  - Go to the Model menu and select Settings
- Others?

Select one of the models listed to investigate as a group (Linear, Free Fall, Vertical Spring, Exponential Decay, Bounded Growth, Predator Prey, Moose Wolf, Carbon Cycle). Answer these questions -

1. What experiment could your students do with this model?
2. What changes would you like to make to this model to tailor it to your needs?

Collect the responses and demonstrate the changes requested. Have copies of the Moose Model Handout and the Advanced Vensim Model Building Handout ready for reference purposes.

Next, let’s build a model from scratch.