

CoreModels

Simple Kinematics

A Core Learning Goals Activity for Science and Mathematics

Summary: Students will use STELLA to build a simple kinematics model which they may then use to answer simple motion problems. This activity assumes no prior knowledge of STELLA.

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Simple Kinematics

Teacher Guide

Overview:

Students will translate their experience with simple kinematics (linear motion) into a computer model. In an extension activity, students may solve simple kinematics problems using a variation of their model.

Prior Knowledge/Skills Required:

Prior to this activity, students should have performed one or more simple linear motion activities. This is an introduction to STELLA, so they do not require any prior knowledge of this software. They should have been introduced to the motion equations and they should be aware of the graphs that result from constant velocity and constant acceleration of motion.

Activities at a Glance:

Activity	Title	Materials	Estimated Time
1	Build a First Physics Model	STELLA, computers	45 min
2	Extensions	STELLA, computers	30 min

Core Learning Goals:

Core Goal 1: Skills and Processes

4. Expectation: The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.

- (3) The student will determine the relationships between quantities and develop the mathematical model that describes these relationships.
- (8) The student will use models and computer simulations to represent systems.

Core Goal 5: Concepts of Physics

1. Expectation: The student will know and apply the laws of mechanics to explain the behavior of the physical world.

- (2) The student will use algebraic and geometric concepts to describe an object's motion.

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Best Practices:

Prior to this activity, students have experimented with linear motion. This could involve a variety of activities including Calculator Based Lab (CBL) activities with the Motion Detector and/or motion labs where students graph the motion of a moving object versus time. These labs are easily found in all Physics Textbook Lab manuals and in several workbooks available for the CBL. Students should have been introduced to the equations of motion and the term rate should be used in these lectures. For example, students should hear that the speed or velocity of an object is the rate of change of distance over time. Using these terms early in the classroom will facilitate students use of the modeling software for future activities.

Students should also have begun to relate type of motion to appearance of graphs. They should be aware of the appearance of distance-time and velocity-time graphs when an object is traveling at constant velocity and when it is traveling at constant acceleration. They should also understand the physical relevance of the slope and y-intercept and what it means if the slope is negative on a distance-time or velocity-time graph.

This first model is the basis for dozens of models which can be introduced in the classroom. Students should be given time to understand the basic functions of the software and how to build the model. When they are finished they should save the basic model. Subsequent models that derive from this model should always be saved with other names so the basic model is available. The extensions introduce further skills.

A scoring tool based on the Common Themes section of the AAAS Benchmarks for Science Literacy is included. A copy of the rubric should be displayed for the students to refer to as they perform the activities. The teacher should explain to the students that the questions marked with an asterisk (*) will be scored using the rubric.


Simple Kinematics Teacher Guide


Activity 1: Building a First Model in Physics

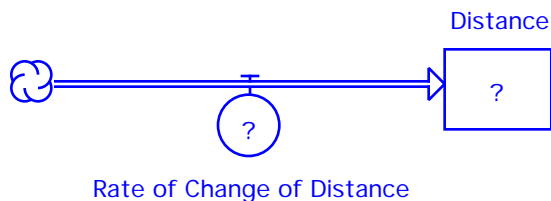
Double click on the **STELLA** icon. When the full screen appears,

click on the icon of the world  once. It should change to an . The top bar looks like this:



This is the source of the icons we will use to build our model. First **click** on the icon that looks like this : . This is known as a stock. Now slide your pointer out into the open field and click again. A large stock should appear with the word **Noname 1** highlighted. Before doing anything else, **type** the word **Distance**.


Now click on the icon which looks like this: . This is a flow. Slide your pointer to a position some distance to the left of the stock, **click and drag** until the arrow just touches the stock and the stock becomes shaded. Let go of the mouse button. Type the word **Rate of Change of Distance**. Your diagram should look like this:



To get rid of the question marks, **double-click** on the Distance stock. When that window opens, **enter** 0 (that's a zero) and **click** on **OK**. Next **double-click** on the Rate of Change of Distance flow. When that window opens, **enter** 7 and **click** on **OK**.

What about units? In physics, all values should be accompanied by units. STELLA can work with any system of units, so the 0 above could be zero feet or zero meters. Likewise, the 7 could be 7 feet per sec, or 7 meters per sec or 7 miles per hour. Unfortunately, STELLA cannot do the math if the numbers have units behind them. There are two ways we can deal with this. We can remember what units we are using or we can put the units in brackets (like this {}), for example 7 {m/s}. Your instructor may want units added.

Now go back to the menu bar and **click** on the graph icon, which looks like

this: . Slide your mouse pointer to a clear spot in the window and **click** again. A small graph icon should appear and immediately be replaced by a large gray graph. **Double-click** anywhere in this graph and a new window will open. In the top center of this window, you will see two boxes which look like the two on the next page:

Allowable			Selected
<input type="checkbox"/> Distance <input checked="" type="checkbox"/> Rate_of_Change_of_...	<div style="border: 1px solid black; padding: 2px; display: inline-block;">>></div>	1.	
	<div style="border: 1px solid black; padding: 2px; display: inline-block;"><<</div>	2.	
	<div style="border: 1px solid black; padding: 2px; display: inline-block;"><..></div>	3.	
		4.	
		5.	

Click on the word **Distance**, then click on the >> symbol. Repeat for **Rate_of_Change_of_Distance**. The boxes would now look like this:

Allowable			Selected
<input type="checkbox"/> Distance <input checked="" type="checkbox"/> Rate_of_Change_of_...	<div style="border: 1px solid black; padding: 2px; display: inline-block;">>></div>	1.	<input type="checkbox"/> Distance
	<div style="border: 1px solid black; padding: 2px; display: inline-block;"><<</div>	2.	<input checked="" type="checkbox"/> Rate_of_Change_of_...
	<div style="border: 1px solid black; padding: 2px; display: inline-block;"><..></div>	3.	
		4.	
		5.	

Click on **OK**.

You should be back at the graph, with the word **Distance** in red at the top and **Rate of Change of Distance** in blue. From the very top menu, Click and hold at the word **Run**, then without letting go of the mouse button, slide down to **Run** on the menu and release. Two graph lines should form on the graph.

Question 1.1: Sketch the graph.

See Appendix A for answer

Note that there are two scales on the y-axis, one for **Distance** and one for **Rate_of_Change_of_Distance**. Lock the graph by clicking on the padlock in the lower left-hand corner of the graph window.

Question 1.2*: Explain why the graph appears as it does.

The velocity is constant, so the graph is a flat line of zero slope. The velocity is causing a constant change in the distance, so the distance graph is a straight line with a positive slope of 7.

Close the graph window by clicking in the square in the upper left-hand corner. Bring a second graph icon to a clear spot in the window and double-click to open it. Select **Distance** and **Rate_of_Change_of_Distance** as the items to graph. To set the scale on Graph 2 to be the same as the scale on Graph 1, highlight **Distance**, click on the double-headed arrow to the right of the **Selected** Box, and set **Min** to 0 and **Max** to 90 and press **Set**.

Highlight **Rate_of_Change_of_Distance**, click on the double-headed arrow to the right, set **Min** to 0 and **Max** to 14 and press **Set**. Click **OK** and use this graph to answer question 1.3.

Making Predictions: Answer the following question without running the model. After you have made your predictions, you can run the model

Question 1.3: How do you think the appearance of the graphs will change and why

a. if the initial distance was changed to 5?

The distance graph will have a y-intercept of 5, but the slope will be the same. The velocity graph will be unaffected. See Appendix B.

b. if the initial distance remained at 0, but the Rate of Change of Distance was changed to 3?

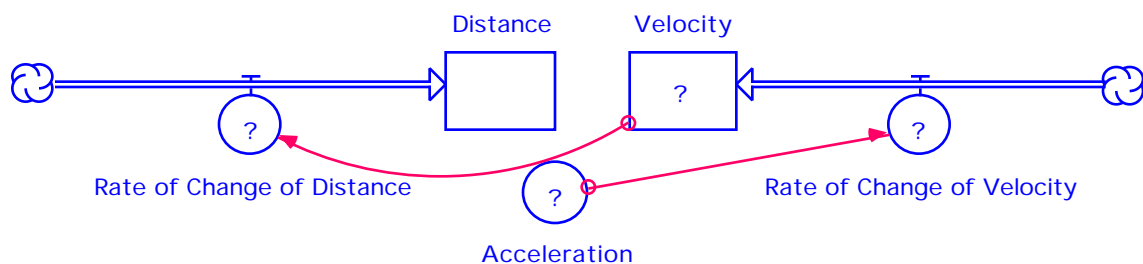
The distance graph will now have a lesser slope than before. The velocity graph will be a flat line at a lower value. See Appendix C. (Note: Students will only see this if the graph axes have been set and are not changing).

Now check your predictions. To do this, first close the graph window. To check your prediction to Question 1.3a, double-click on the Distance stock and replace the 0 with 5. Click OK, run the model and check Graph 2. Note any changes. To check your prediction to Question 1.3b, change the Distance stock back to 0 and then change the Rate of Change of Distance flow to 3. Click OK, run the model and check the Graph 2.

Question 1.4: Were your predictions correct? Describe any discrepancies and explain why the results were different from your predictions.

Student answers will vary.

Adding Acceleration: Close the graph window by clicking on the box in the upper left hand corner. Change your model so that it looks like this:



The circular icon, Acceleration, is known as a converter. It can be found to the right of the flow on the tool bar. Click there once, then position the

cursor on the diagram and click again. The line with a circle on one end and an arrow on the other is a connector. It is to the right of the converter on the tool bar. Click on the red arrow in the tool bar, then position the cursor inside the Acceleration converter, click and drag until the arrow touches the Rate of Change of Velocity flow and release. Repeat for connecting Velocity to Rate of Change of Distance.

Double-click on the Rate of Change of Distance icon, and when the window opens, choose Velocity from the Required Inputs box. **Click OK. Double-click** on the Velocity icon and **type 0** (zero) and **OK. Double-click** on the Rate of Change of Velocity icon and choose Acceleration from the Required Inputs box and **OK. Double-click** on the Acceleration icon and **type 3** and **OK.**

Question 1.5: Earlier the Rate of Change of Distance was equal to a constant (7). Why can we now equate Rate of Change of Distance with Velocity?

Velocity and Rate of Change of Distance are the same thing (definition). The object is accelerating, so the velocity will be changing as will the rate of change of distance.

Create a third graph as you did with the other two, but select **Distance**, **Velocity** and **Acceleration** this time. Do not set the scales. Run the model again.

Question 1.6*: Sketch the graph and explain the appearance of the graph.

The acceleration graph is a flat line because it is constant. The velocity graph is a straight line with a slope equal to the acceleration because it is changing. The distance graph is a half-parabola because as the velocity keeps increasing, larger distances are being covered every second. See Appendix D.

Making Predictions: Answer the following question without running the model. After you have made your predictions, you can run the model

Question 1.7: Describe how you think the appearance of the graphs will change and why:

- a. if the initial velocity was changed to 5?

Velocity graph starts with a y-intercept. Distance graph will have a sharper upward curve.

b. if the initial velocity remained at 0, but the Acceleration was changed to 5?

The acceleration graph will be in a different position, the velocity graph will have a steeper slope and the distance graph will have a sharper slope or rise.

Run the model and check your predictions.

Question 1.8: Were your predictions correct? Describe any discrepancies and explain why the results were different from your predictions.

Student answers will vary.

Activity 2: Extensions

In the first worksheet, you were asked about the effects of changing initial distances and velocities and about the effect of changing the flow values. In this activity, we will examine the effect of several changes on the model. At the same time, we will learn about some other features that STELLA has to offer.

Experiment with changing the acceleration values, the initial velocity and the initial distance. Remember to use appropriate testing procedures (change one variable at a time). For the moment, keep all values positive.

Question 2.1*: What were the effects on the graphs when you changed each of these variables.

Changing the initial value of either the distance or velocity changes the position of the y-intercept for that variable. In addition, changing the initial value for the velocity.

Question 2.2: Predict the effect of having a negative acceleration. What will all the graphs look like, if the initial distance and velocity start at zero? You can answer with sketches.

Student predictions

To check your prediction, you need to make the following changes in the model. **Double-click** on the Distance stock and in the upper left corner of the dialog box, click in the Non-negative box so that it is blank (no X). Click on **OK**. Repeat this for the Velocity stock. This allows both of these variables to go negative. Now **double-click** on the Rate of Change of Distance flow and in the upper left corner of that dialogue box, click in the bi-flow bullet. Click **OK**. Repeat for the Rate of Change of Velocity flow. This allows the flows to add or subtract amounts from the stock. Now change the acceleration to a negative value (try -3) run the model and observe the graph.

Question 2.3*: Sketch and explain the appearance of the graph.

Student sketch

The acceleration graph will still be a flat line, but the value of that line will be negative. The velocity graph will be a straight line of negative slope equal to the acceleration. The distance half-parabola will arch downward traveling increasing larger negative distances. See Appendix E.

Model a car accelerating, traveling at constant velocity and then decelerating. **Double-click** on the acceleration converter. Type the following in place of the value you used above

```
If (Time < 3) then 5 else if (time >9) then -5 else 0
```

This statement says, that if time is less than 3 seconds, the car will accelerate at 5, it will stop accelerating at all between 3 and 9 seconds and then at 9 seconds, it will decelerate at the rate of -5.

Question 2.4: What do you think the velocity and distance graphs will look like? Why?

Student predictions

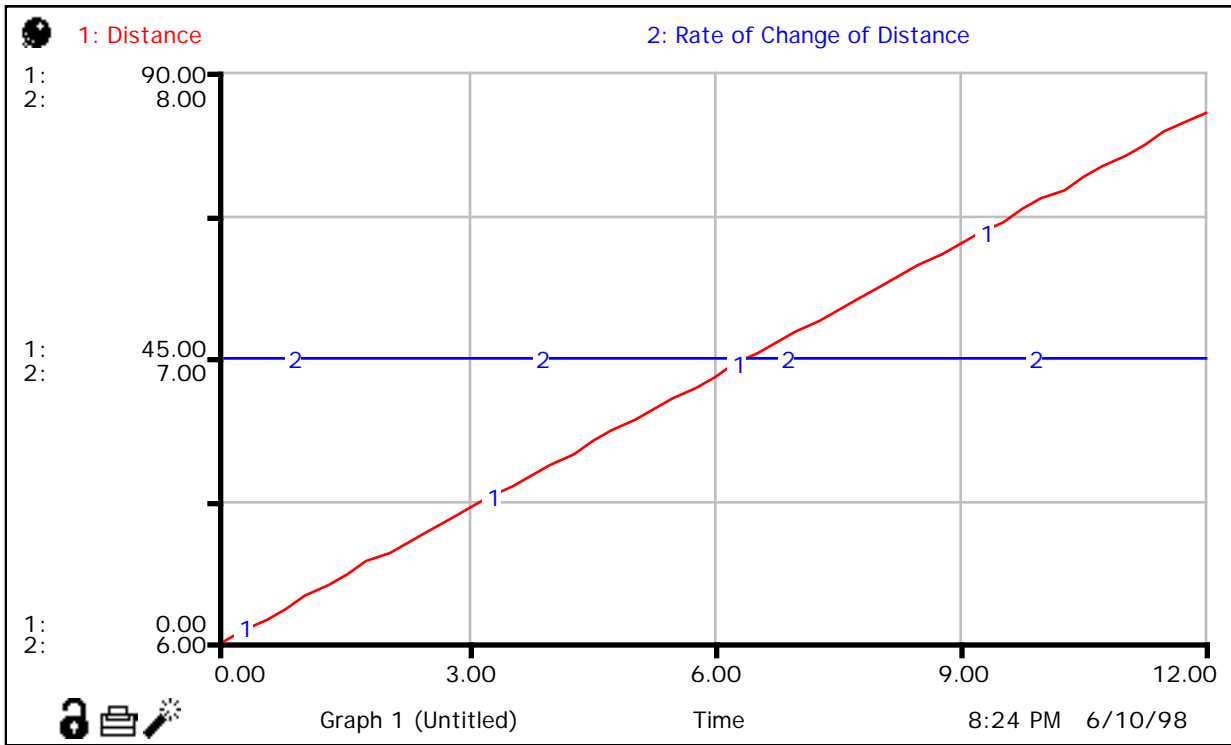
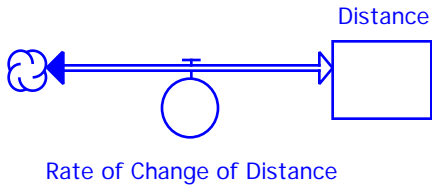
Run the model and observe the graphs.

Question 2.5: Compare the graph created by the model to your prediction.

The model graph shows the stepwise nature of the acceleration, the velocity graph rising for three secs, flat-line for 6 secs and then falling for 3 secs. The distance graph shows a parabolic section for the first 3 seconds, a straight line portion for 6 secs and a decreasing parabola for the last 3. See Appendix F.

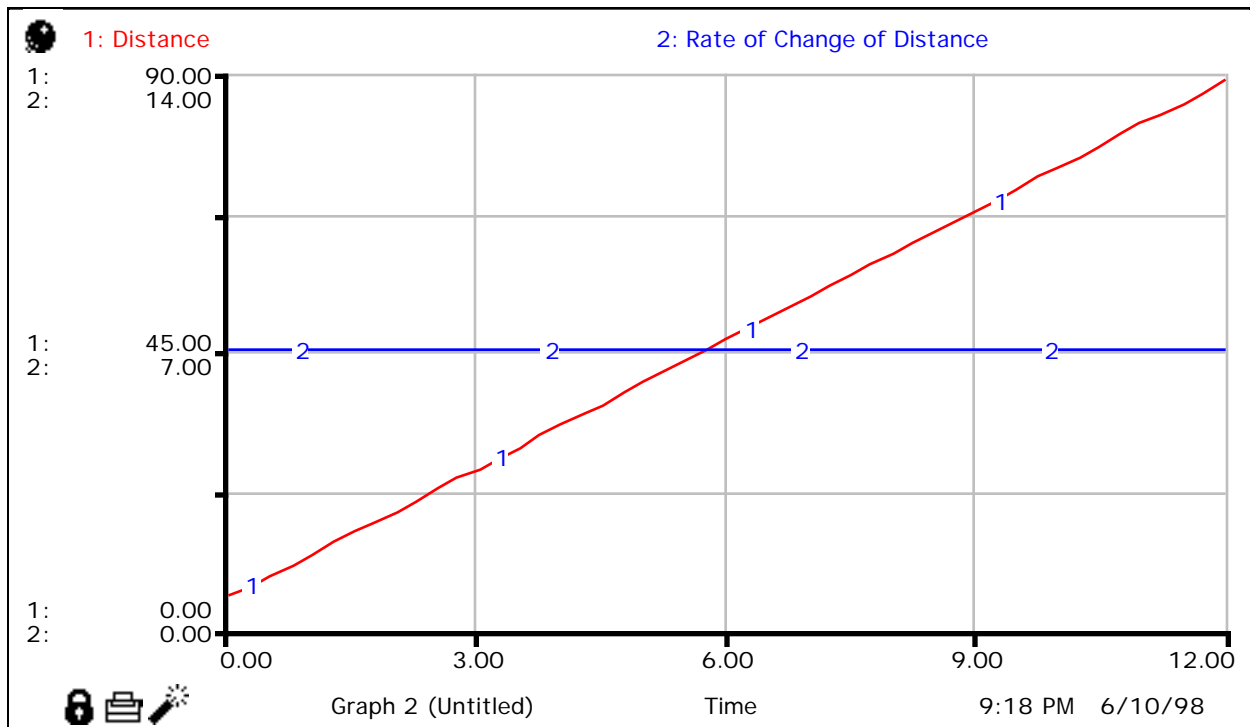
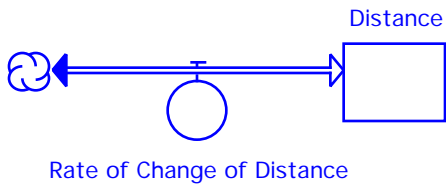
Appendix A

Stella Model-Constant Velocity



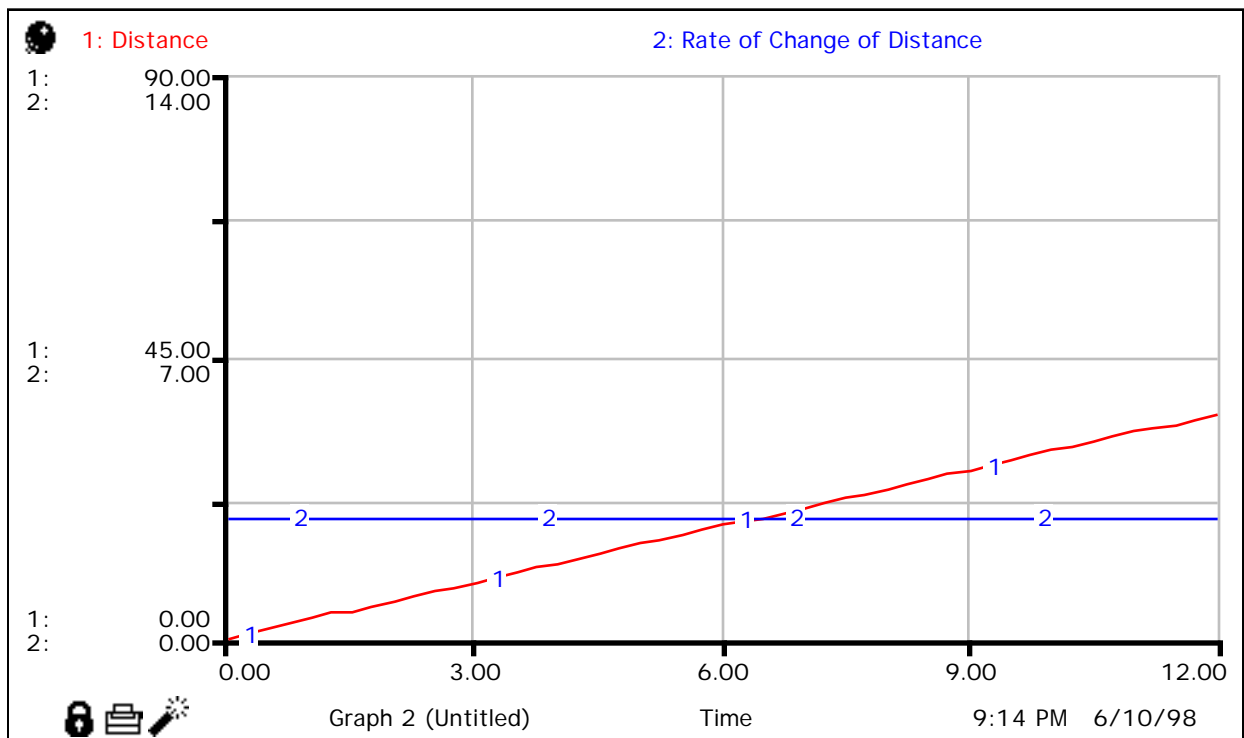
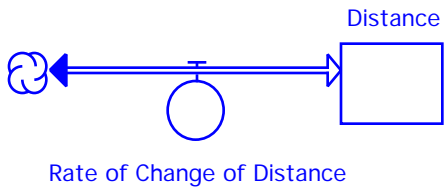
Appendix B

Stella Model-New Initial Distance



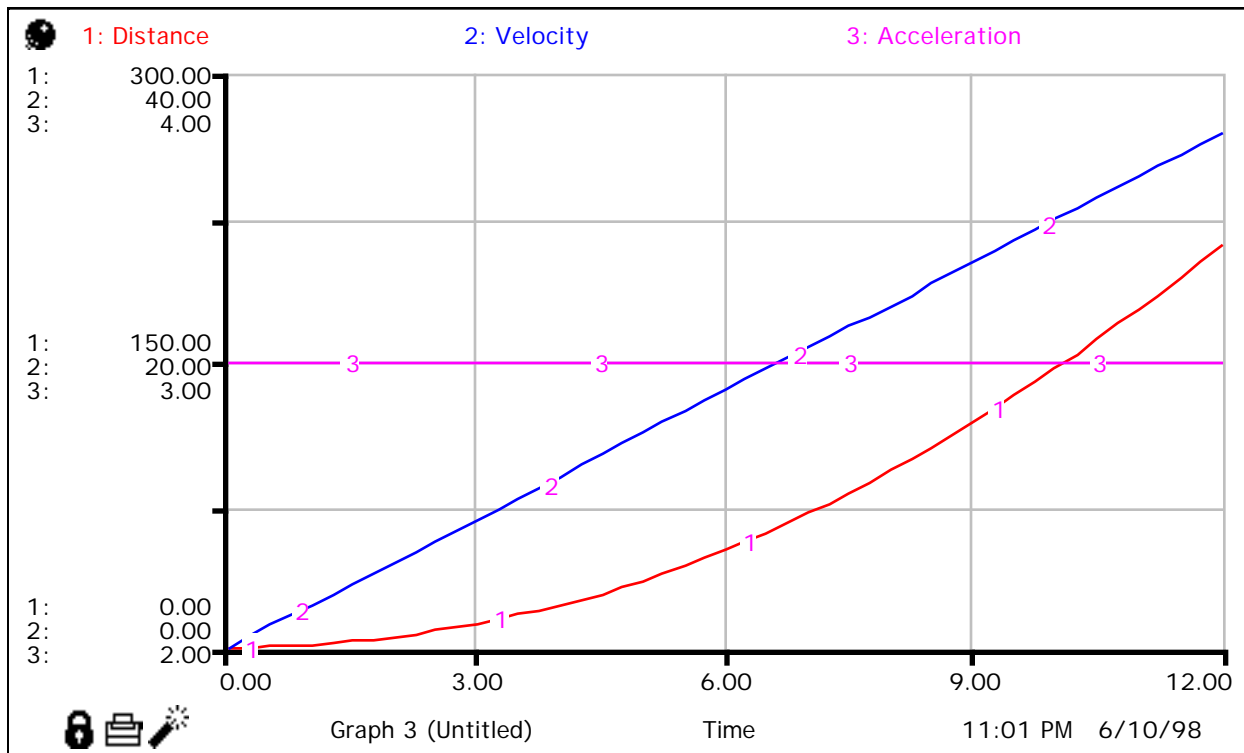
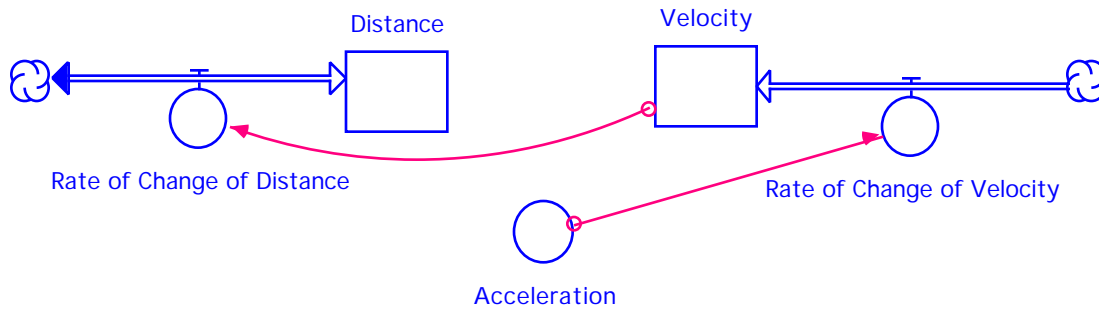
Appendix C

Stella Model-New Velocity



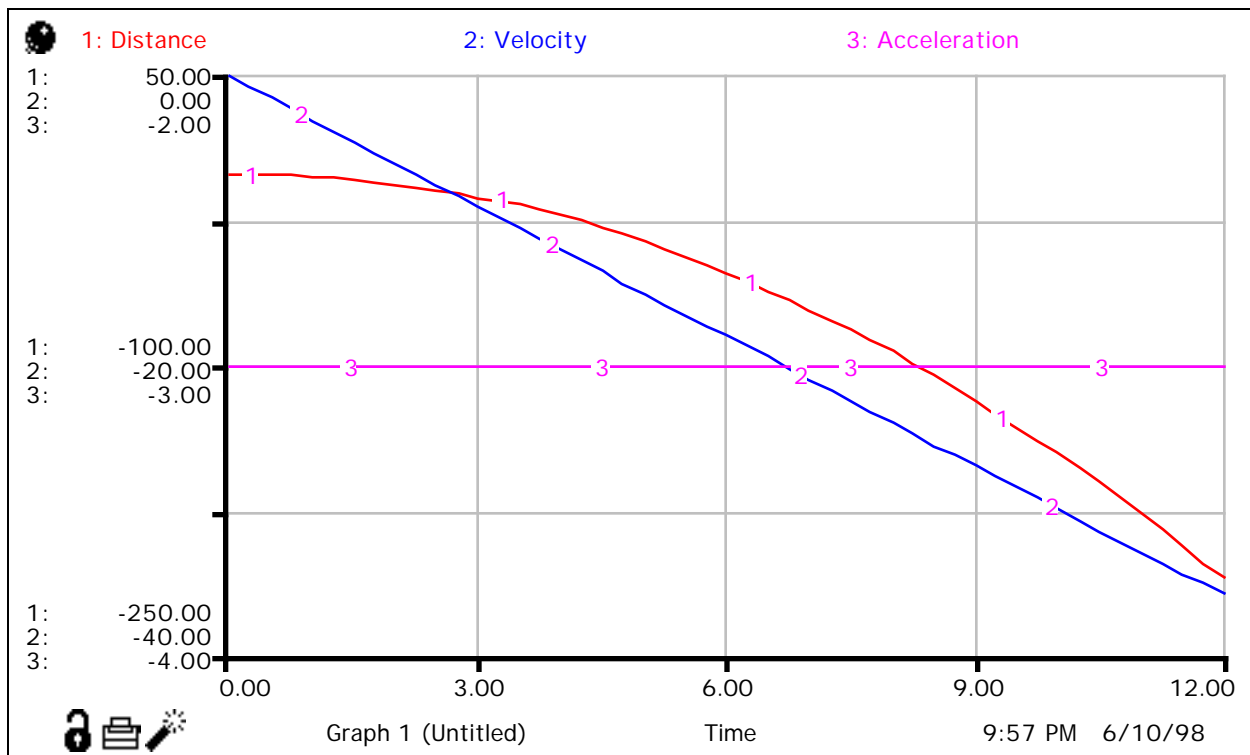
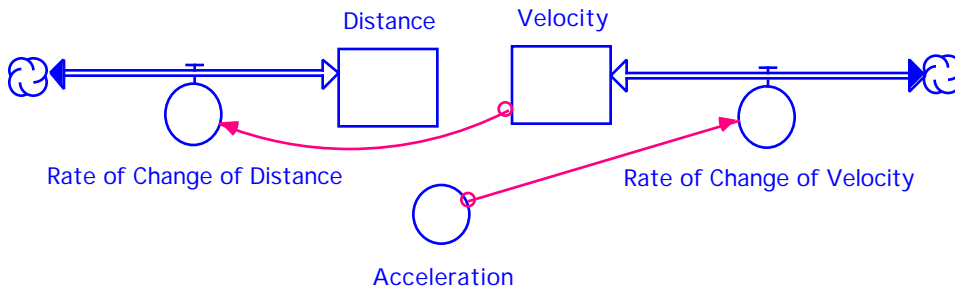
Appendix D

Stella Model-Positive Acceleration



Appendix E

Stella Model-Negative Acceleration



Appendix F Stella Model-Varying Acceleration

