

# CoreModels

## FreeFall

### A Core Learning Goals Activity for Science and Mathematics

**Summary:** This model is an extension of the Simple Kinematics model, turned in the vertical direction and with an initial distance and a negative acceleration.

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Based on Picket Fence suggestion from Vernier Software, <http://www.vernier.com>

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**FreeFall**  
**Table of Contents**

	Page
Teacher Guide	T1-T6
Appendices	
A. STELLA Model-Simple Free Fall Model	A1-A2
B. STELLA Model-Wrench and Helicopter	A3-A4

# FreeFall Teacher Guide

One body, one dimension

## Overview:

This model is an extension of the Simple Kinematics model, turned in the vertical direction and with an initial distance and a negative acceleration.

## Activities at a Glance:

Activity	Title	Materials	Estimated Time
1	Which Falls Faster?	ball, sand, parachute, textbook, paper, film canister	20 min
2	The Picket Fence	CBL, photogate, plexiglass	45 min
3	Free-Fall Model	STELLA, computers	45 min
4	The Wrench and Helicopter Problem	STELLA, computers	30 min

## Prior Knowledge/Skills Required:

The student should be familiar with the terms and equations involving distance (displacement), velocity and acceleration. The student should be accustomed to using the acceleration due to gravity as a negative number, descending velocities as negatives and heights as positive. The student should be aware that an object with an upward velocity, when freed from the agent lifting it, will continue on an upward direction as it slows down.

## Best Practices:

Students can approach the freefall model one of two ways. If they start with the simple kinematics model they will need to change the flows to biflows and allow the velocity stock to be negative. They will also need to input an initial distance for the object to start at. If they build the model from scratch, then they should have the flows exit the stocks. This presents an excellent opportunity for discussing the choice of direction of a flow. Students could use this model to investigate different accelerations due to gravity (such as the moon). They could use comparative graphs to allow direct comparison.

In the wrench and helicopter problem in Activity Four, an object (in this case a wrench) is rising with another object (the helicopter) when it falls off. This problem is similar to the car/truck problem from Simple Kinematics except that now both objects start with the same velocity, but only one is affected by acceleration. Also, the problem uses the student's newfound knowledge about freefall. The student could start with the car/truck model and change it for

the vertical direction or the student could begin with the freefall model and include a second object. If starting with car/truck, the flows need to be changed to biflows and the velocity stock for the wrench must be allowed to be negative. This time, both objects have an initial vertical velocity. The student could include an if-then statement to have the objects move together for a period of time before the wrench falls. The student needs to set the axes so that they are the same for both objects when graphing distances otherwise they won't be able to compare the relative positions between them.

### **Core Learning Goals:**

#### **Core Goal 1: Skills and Processes**

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

Indicator 4: The student will check graphs to determine that they do not misrepresent results by using inappropriate scales or by failing to specify the axis clearly.

Indicator 8: The student will use models and computer simulations to represent systems.

#### **Core Goal 5: Concepts of Physics**

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

Indicator 2: The student will use algebraic and geometric concepts to describe an object's motion.

## FreeFall Teacher Guide

**Introduction:** What influences how an object falls to the ground? Do the same factors need to be taken into consideration for a golf ball dropped from your hand, an open parachute, and a meteor from when it enters the earth's atmosphere until it meets the ground?

**Activity One:** Which Falls Faster?

1. List all of the factors that you think influence how fast an object is moving when it is released from a distance above the ground. Don't try to distinguish when these factors are important in this step:

Surface area, acceleration due to gravity, mass, air density

2. For each pair of objects, which one will be traveling at a higher velocity when it hits the ground? Or will both be traveling at about the same speed?

empty ball/ball with sand — same speed —

closed parachute/open parachute — closed parachute —

empty ball/ball with sand with parachutes — empty ball —

**Teacher Demonstration:**

Your teacher will drop the following pairs of objects simultaneously. Predict which will be traveling faster when it hits the ground. Then record your observations of the teacher demonstration.

A textbook or a piece of paper — textbook —

Observations:

student answers will vary

A textbook or a crumpled piece of paper — same —

Observations:

student answers will vary

An empty film canister or a filled film canister — same —

Observations:

student answers will vary

Summarize what you have learned about falling objects:

**Surface area is more important than mass in determining how fast something falls. When surface area is the same (or similar), two objects of different mass fall at the same rate.**

**Activity Two:** The Picket Fence

Introduction: In this activity you will use a CBL, photogate and a Picket Fence to explain the motion of falling objects. The picket fence is a plexiglass strip divided into alternating dark and clear strips of equal width. When the strip moves through a photogate interfaced to a CBL and calculator, time intervals are measured for the passage of successive dark strips through the gate. The raw data can then be converted to graphs of distance vs. time, velocity vs. time and acceleration vs. time.

Procedure:

1) Before performing the lab, answer the following:

a) For an object like the picket fence, will the motion be constant velocity, constant acceleration or something else?

**constant  $a = 9.8 \text{ m/s}^2$**

b) For an object with a parachute attached, will the motion be the same or different than in a)? If different, how so?

**$a$  is decreased due to drag of the parachute**

2) Position a photogate on its stand sideways so that it extends over a table end. Put a soft object (bookbag?) on the floor below the gate. Connect the photogate to the CBL using channel 1 (CH1) . Connect the CBL to a calculator using the linking cable. Turn the CBL on, then the calculator.

Open the program menu by touching the PRGM key on the calculator. Select the program TIMER. At the opening screen, press ENTER. The next screen just reminds you to connect the photogate, so press ENTER. From the next menu choose 2. CHECK GATE and follow the instructions.

Then choose 1. TIMING MODES. From the next menu choose 1. MOTION, then 1. SELECT DEVICE, then 1. VERNIER PICKET, then 2. COLLECT DATA.

Position the Picket Fence just above the photogate, hit ENTER to Arm Gate and drop the Picket Fence through the gate.

At this point, the program will allow you to view the d-t, v-t , and a-t graphs individually. Show your instructor the d-t graph. Sketch each graph in turn and include a rationale for the shape of each graph.

Then choose the STATS option from the menu and copy down the first and third screens as shown. Finally, use the RETURN options until you QUIT the program. Then click on the STAT button on the calculator. Choose the Edit option and record the values found in lists 1, 2, 4 and 6.

Now delete the zeros in the first row of L<sub>1</sub> and L<sub>2</sub>. Then choose STAT followed by CALC, then B:PwrReg. The calculator returns to the screen with PwrReg. Type L<sub>1</sub>, L<sub>2</sub> hit enter and record the data.

Share your data with the class.

### **Activity Three: STELLA FreeFall Model**

In this activity, you will modify a previous STELLA model to represent your new knowledge about free-fall.

Open the velocity - acceleration model previously saved. Edit the model so that it shows freefall. This will involve several changes.

1. Since acceleration due to gravity is negative, we will be taking "stuff" out of the stocks. This means that the flows must be biflows. Double click on each flow and when the dialogue box appears, click in the biflow circle.
2. We are now starting with an initial height, so change the initial Distance value to something larger than zero.
3. Our initial velocity is still zero, but the velocity will be negative (Why?). Open the dialogue box for the velocity box and un-'X' the Non-negative box.
4. Change the acceleration to  $-9.81 \text{ {m/s}^2}$

**Question 3.1:** Run the model and sketch the graphs below.

**See Appendix A**

**Question 3.2:** What differences exist between your STELLA graphs and those that were on the calculator? Why?

**The calculator shows distance and velocity graphs with positive slopes. The STELLA graphs have negative slopes. STELLA uses gravity as a negative number, while the calculator treats gravity as a positive number.**

**Question 3.3:** Which set of graphs is preferred? Why?

**Gravity is generally defined as a negative number so STELLA graphs are preferred. The STELLA graph also shows the height decreasing as the object is falling.**

The acceleration due to gravity on the Moon is 1/6 that of Earth. We want to compare the effects of the two different gravities. STELLA allows comparative graphs, but only of one variable. Open the graph dialogue box, click on the comparative box and choose Distance for this graph. Then make a

new page for the velocity graph (see the arrows and word new in the lower right corner of the dialogue box) and make this comparative as well. Finally, create a third page for comparing accelerations. Run the model for the current settings, then adjust your model for the Moon and run again. Two lines should appear on each graph.

**Question 3.4:** Record your comparison below.

**See Appendix A**

Reset the acceleration for Earth and save the model as Freefall.

**Activity Four:** The Wrench and Helicopter Problem

This problem is similar to the car-truck problem except that now both objects start with the same velocity, but only one is affected by acceleration. Also, the problem uses your newfound knowledge about freefall.

**Problem:**

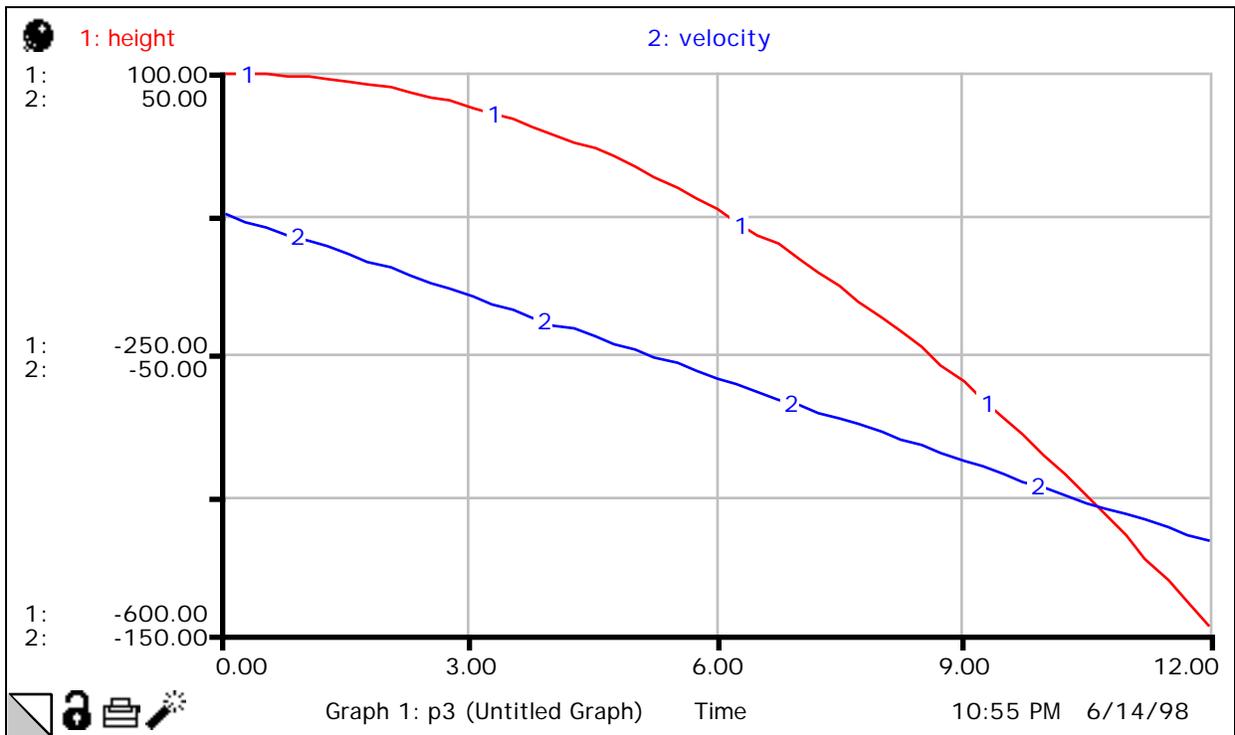
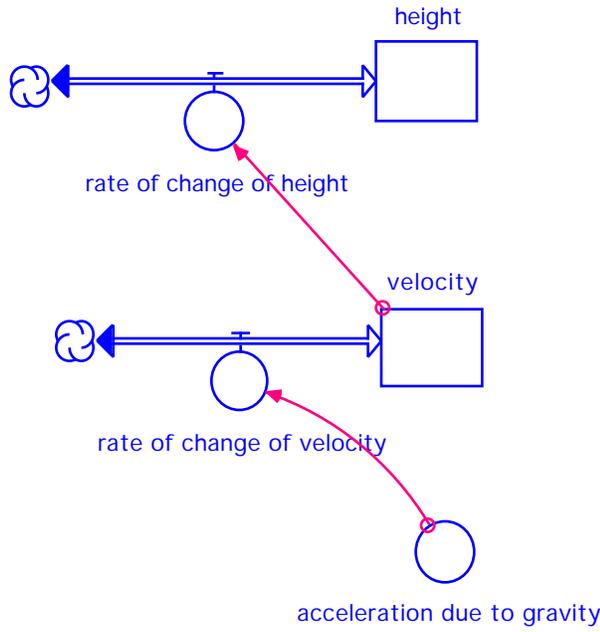
A wrench falls from a helicopter which is rising steadily at 6.0 m/s. After 2.0 s

- a. what is the velocity of the wrench? **13.6 m/s**
- b. how far below the helicopter is the wrench? **19.4 m**

**Hint for building the model:** Make separate stocks for the helicopter's distance and the wrench's distance. Then have the appropriate flows based on your earlier models. Remember the wrench is accelerating and in free-fall, but the helicopter is not. The graph should show the distance traveled by both the helicopter and the wrench.

**See Appendix B**

## APPENDIX A Simple Free Fall

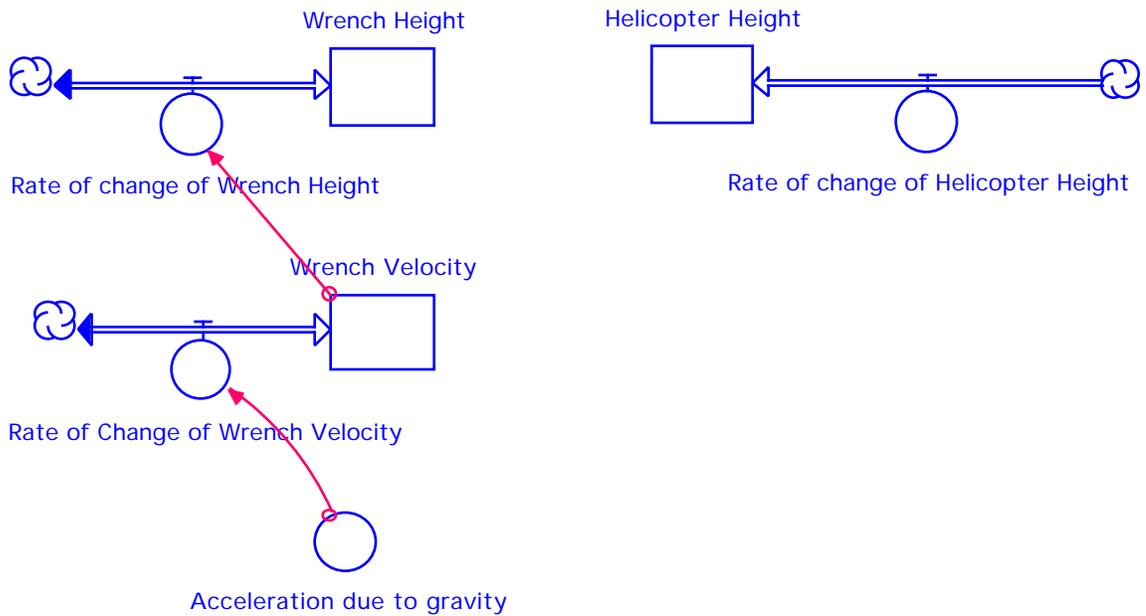


## Equations

```
Height(t) = Height(t - dt) + (Rate_of_change_of_Height) * dt
INIT Height = 100
Rate_of_change_of_Height = Velocity
Velocity(t) = Velocity(t - dt) + (Rate_of_Change_of_Velocity) * dt
INIT Velocity = 0
Rate_of_Change_of_Velocity = Acceleration_due_to_gravity
Acceleration_due_to_gravity = -9.8
```

## APPENDIX B Wrench and Helicopter

### Diagram



### Equations

```

Helicopter_Height(t) = Helicopter_Height(t - dt) +
    (Rate_of_change_of_Helicopter_Height) * dt
INIT Helicopter_Height = 10
Rate_of_change_of_Helicopter_Height = 6
Wrench_Height(t) = Wrench_Height(t - dt) +
    (Rate_of_change_of_Wrench_Height) * dt
INIT Wrench_Height = 10
Rate_of_change_of_Wrench_Height = Wrench_Velocity
Wrench_Velocity(t) = Wrench_Velocity(t - dt) +
    (Rate_of_Change_of_Wrench_Velocity) * dt
INIT Wrench_Velocity = 6
Rate_of_Change_of_Wrench_Velocity = Acceleration_due_to_gravity
Acceleration_due_to_gravity = -9.8
    
```

