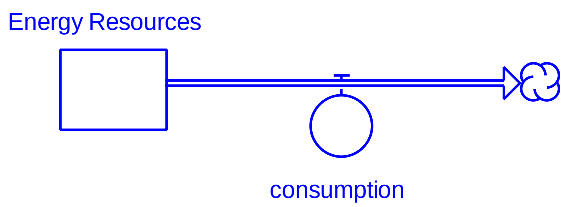
Beginner Modeling Exercises



Prepared for the
MIT System Dynamics in Education Project
Under the Supervision of
Prof. Jay W. Forrester

by
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Vensim Examples added October 2001

Table of Contents

1. ABSTRACT

The goal of this paper is to teach the reader how to distinguish between stocks and flows. A stock is an accumulation that is changed over time by inflows and outflows. The reader will gain intuition about stocks and flows through an extensive list of different examples and will practice modeling simple systems with constant flows.

2. INTRODUCTION

What is the difference between a stock and a flow? Stocks are accumulations. Stocks hold the current state of the system: what you would see if you were to take a snapshot of the system. If you take a picture of a bathtub, you can easily see the level of the water. Water accumulates in a bathtub. The accumulated volume of water is a stock. Stocks fully describe the condition of the system at any point in time. Stocks, furthermore, do not change instantaneously: they change gradually over a period of time.

Flows do the changing. The faucet pours water into the bathtub and the drain sucks water out. Flows increase or decrease stocks not just once, but every unit of time. The entire time that the faucet is turned on and the drain unplugged, water will flow in and out. All systems that change through time can be represented by using only stocks and flows.

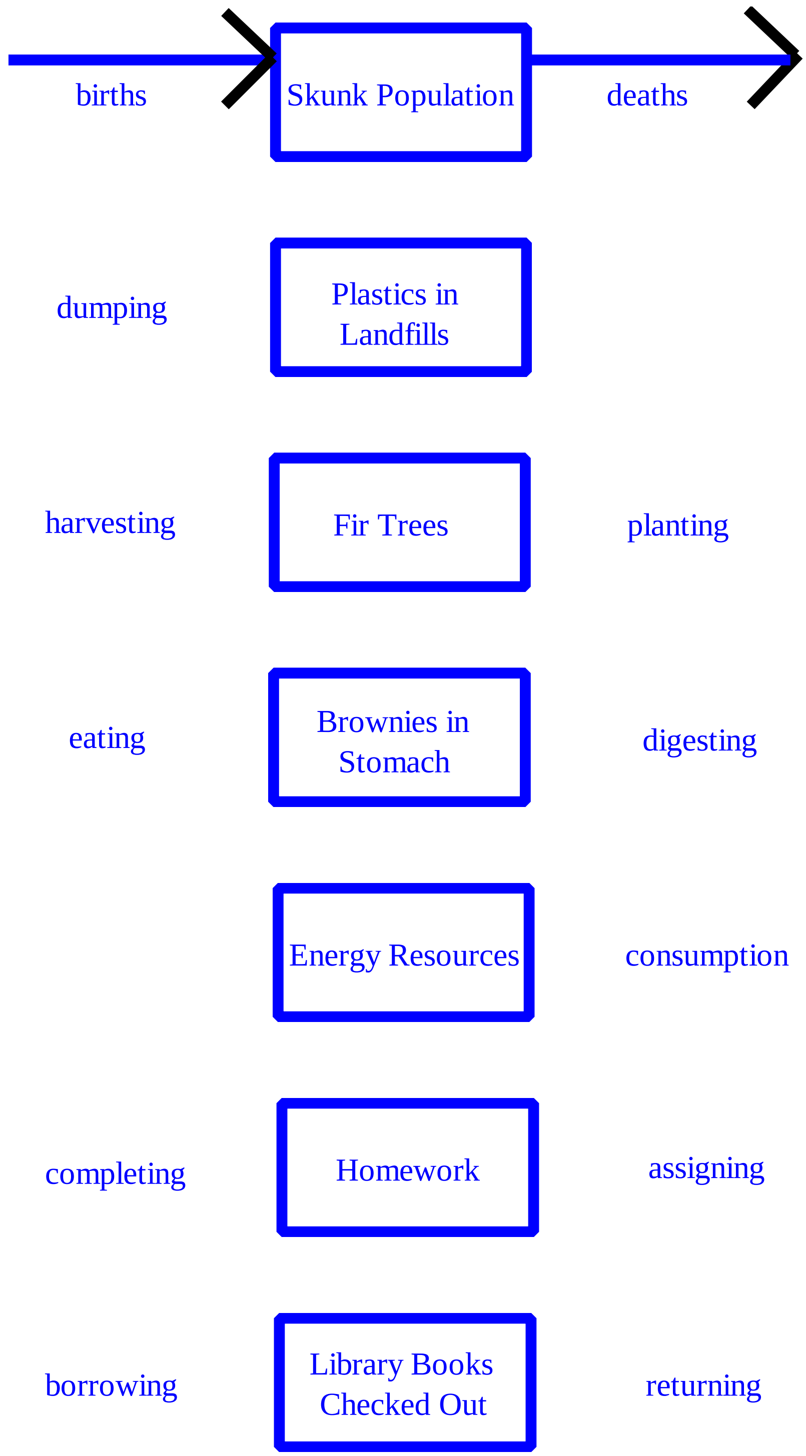
3. STOCKS AND FLOWS

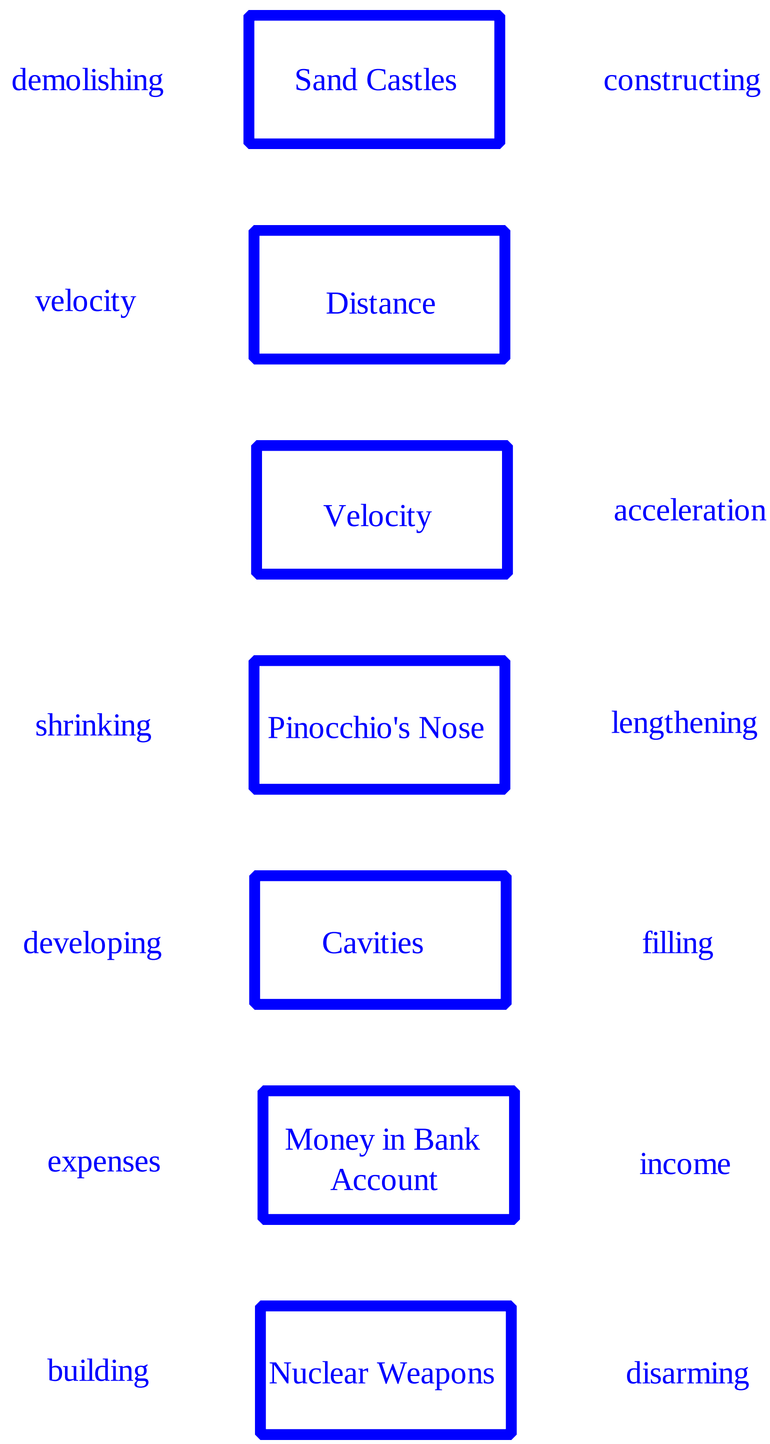
Below are fourteen rows of variables. For each row, identify which variable is a stock and which are the flows that change the stock. Draw a box around the stock. The first row has already been done as an example. The population of skunks is a stock. The size of the skunk population changes with a number of births each year and a number of deaths each year.

births	deaths	$\boxed{\text{skunk population}}$
dumping	plastics in landfills	
harvesting	fir trees	planting
brownies in stomach	eating	digesting
consumption	energy resources	
completing	assigning	homework
returning	borrowing	library books checked out

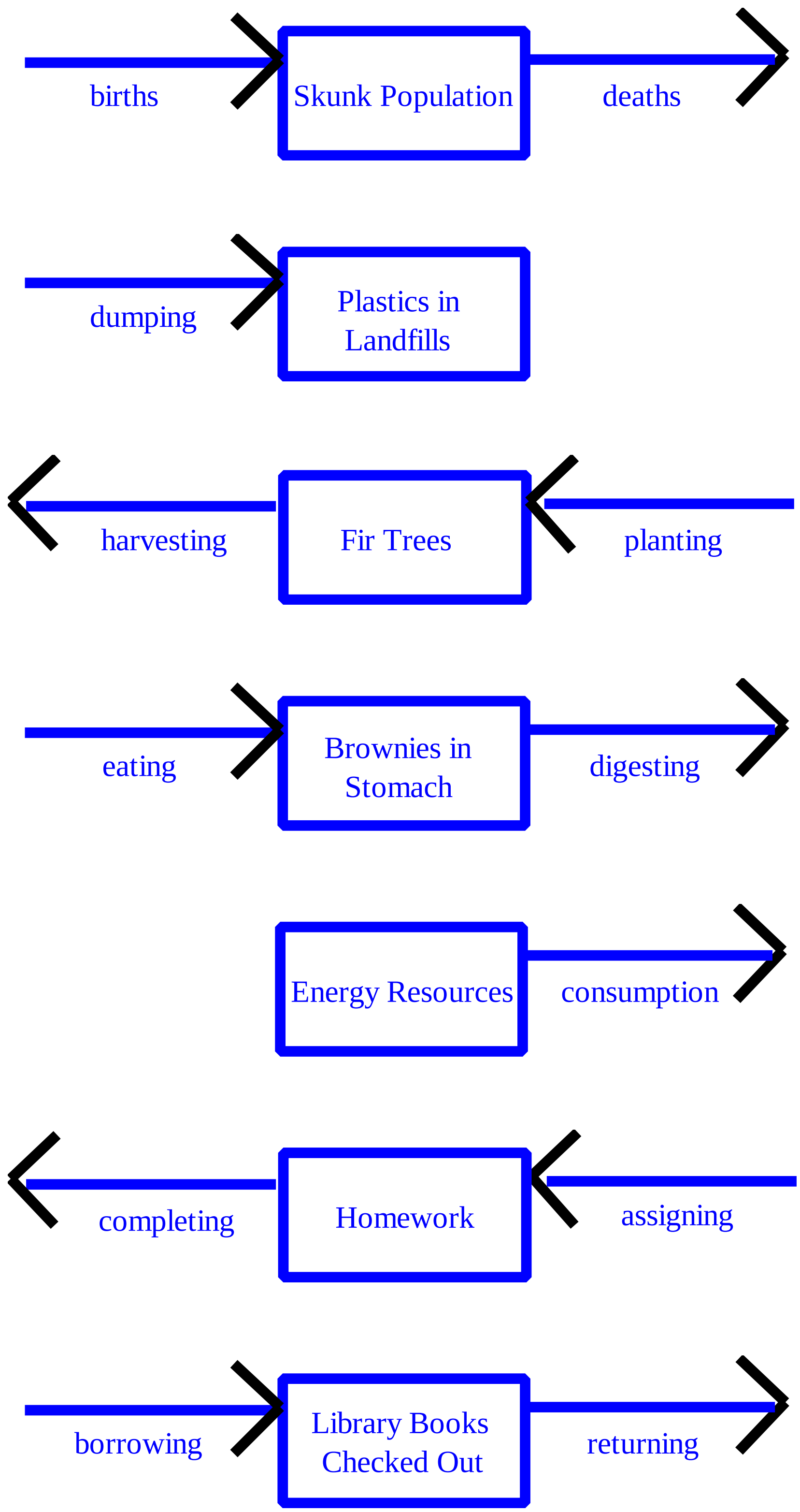
velocity	distance	
velocity	acceleration	
sand castles	demolishing	constructing
shrinking	Pinocchio’s nose	lengthening
cavities	developing	filling
expenses	income	money in bank account
building	nuclear weapons	disarming

The solution is pictured below. The stocks are in the center, boxed, and the flows are on the outside. Now determine which flows are inflows and which are outflows by drawing arrows into or out of the stocks. The first row has been done as an example. The skunk population is *increased* by births and *decreased* by deaths.

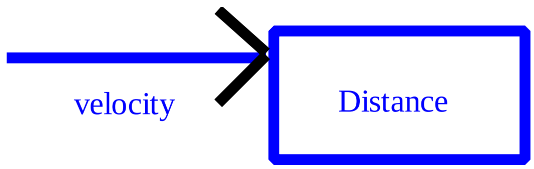


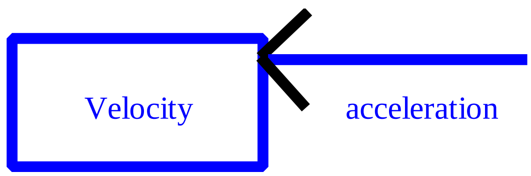

demolishing
Sand Castles
constructing
velocity
Distance
Velocity
acceleration
shrinking
Pinocchio's Nose
lengthening
developing
Cavities
filling
expenses
Money in Bank Account
income
building
Nuclear Weapons
disarming

The solution is depicted below:

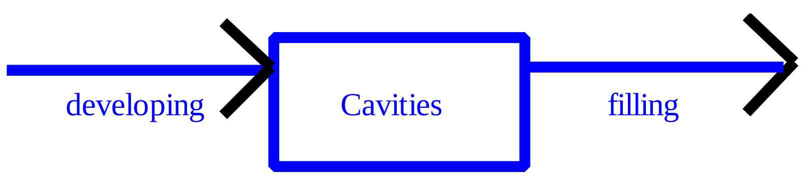



demolishing
Sand Castles
constructing


velocity
Distance


Velocity
acceleration


shrinking
Pinocchio's Nose
lengthening


developing
Cavities
filling


expenses
Money in Bank Account
income


building
Nuclear Weapons
disarming

4. MODELING WITH STELLA

4.1 Skunks

Scenario: Five hundred skunks live in the wooded grassy area near the intersection of two interstate expressways. Every year 100 baby skunks are born. Life on a highway takes its toll, though, and every year 120 skunks die.

Question: How many skunks will live near the highway in 10 years?

? Open a new STELLA file.

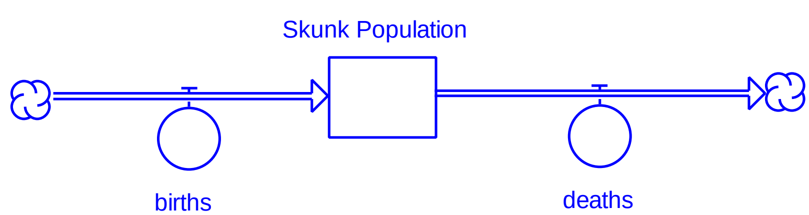
? Go down to the model construction level by clicking on the down arrow ( ).

? Place a stock ( ) in the middle of your screen and name it "Skunk Population."

? Place a flow ( ) to the left of the "Skunk Population" stock and drag the flow into the stock. Name the flow "births."

? Place a flow in the "Skunk Population" stock and drag the flow to the right. Name the flow "deaths."

Your model will look like the model below:



? To go to the equations mode, toggle the globe in the upper-left-hand corner ( ) so that it becomes . Question marks should appear in the stock and flow.

? Double-click on “births” and the dialog box will appear on your screen. Type “100” as the equation for “births.”

? Click on the *Document* button. In the document box, type “100 baby skunks are born every year.”

? On the next line type “UNITS: skunks/year.” Click OK.

? Double-click on “deaths” and the dialog box will appear on your screen. Type “120” as the equation for “deaths.”

? Click on the *Document* button. In the document box, type “120 skunks die every year.”

? On the next line type “UNITS: skunks/year.” Click OK.

? Double-click on the “Population” stock and the dialog box will appear on your screen. Type “500” as the initial skunk population.

? Click on Document. Type “The initial skunk population is 500 skunks.”

? On the next line type “UNITS: skunks.” Click OK.

To view the equations for the model you have just created, click on the down arrow ( ) above the icon. Then select Equation Prefs under the Edit menu. Once the Equation Prefs dialog box appears on your screen, click on Show Documentation. Click OK. The following equations will appear:

□**Skunk_Population**(t) = Skunk_Population(t - dt) + (births - deaths) * dt

INIT Skunk_Population = 500

DOCUMENT: The initial skunk population is 500 skunks.

UNITS: skunks

births = 100

DOCUMENT: 100 baby skunks are born every year.

UNITS: skunks/year

deaths = 120

DOCUMENT: 120 skunks die every year.

UNITS: skunks/year

You will notice that you typed in the information for everything except the first equation for "Population." Every stock equation is automatically formulated by STELLA when you diagram the flows, so all you need to do is define an initial value.

? Click on the up arrow ( ) to return to the model construction level.

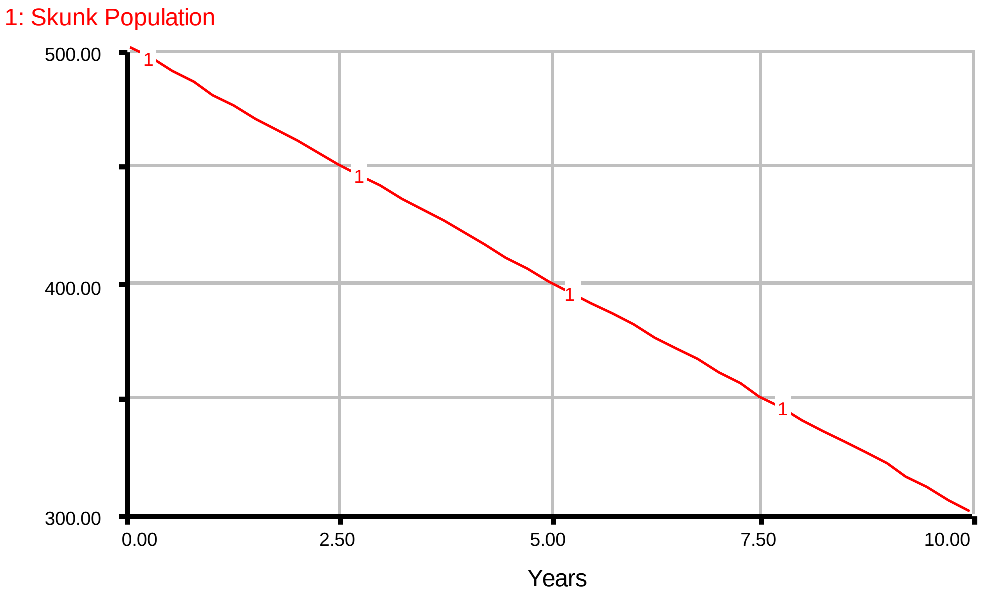
? Create a graph by clicking the graph icon ( ) and placing it onto the workspace. Double-click on the icon.

? Double-click on the graph pad itself to open it. When the dialog box opens, name the graph "Skunk Population." Double-click on "Population" from the Allowable Inputs list to select it to be graphed. Click OK.

? Select Time Specs in the Run menu. When the dialog box appears, select "Years." Set the Range values from 0 to 10. Click OK.

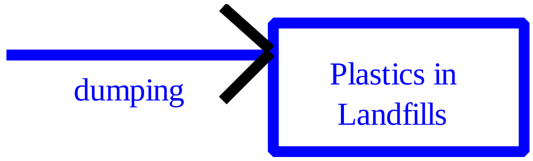
? To run the graph, either select Run from the Run menu, hold down both open-apple (⌘) and "R," or click on the little runner to bring up the run controller window and click on the play button.

You will see the graph replicated below:



One quick glance at the graph will give you the answer to our question: Ten years from now, 300 skunks will populate the grassy area beyond the interstate.

4.2 Landfills



Scenario: The city of Boise, Idaho is building a new landfill. The city council wants to know how large the landfill will be in twenty years so that it can plan ahead and allocate enough space for all of the trash that will be dumped into the landfill. The trash in the landfill can be separated into two categories: the trash that will quickly decompose, like yard leaves, and the trash that will take a long time to decompose, like plastics. The city council predicts that, over the next twenty years, the citizens of Boise will be dumping approximately five thousand gallons of plastics into the landfill every day.

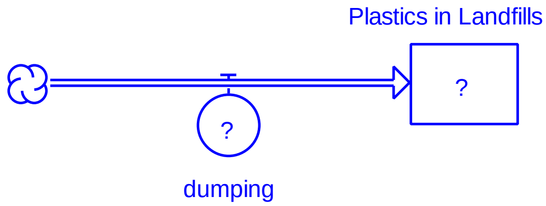
Question: How many gallons of plastics will the Boise landfill contain in twenty years time?

? Dynamite the skunk population model by positioning the dynamite icon ( ) over the stock and flows.

? Place a stock ( ) in the middle of your screen and rename it "Plastics in Landfills."

? Place a flow ( ) to the left of the "Plastics in Landfills" stock and drag the flow into the stock. Rename the flow "dumping."

The plastics will not significantly decompose over a period of 20 years, so you do not need to add an outflow to the stock of "Plastics in Landfills." Your model will look like the model below:



The citizens of Boise dump 5,000 gallons of plastics a day into the landfill. Because there are on average 365 days in a year, the citizens of Boise dump 5,000 * 365 gallons of plastics each year.

? Double-click on “dumping” and the dialog box will appear on your screen. Type “5000 * 365” as the equation for “dumping.”

? Click on the *Document* button. In the document box, type “Citizens in Boise will dump 5,000 gallons of plastics into the landfill every day for the 365 days that make up a year.”

? On the next line type “UNITS: gallons of plastics/year.” Click OK.

? Double-click on the “Plastics in Landfills” stock and the dialog box will appear on your screen. Type "0" as the initial skunk population.

? Click on Document. Type "Initially the landfill is empty."

? On the next line type “UNITS: gallons of plastics.” Click OK.

To view the equations for the model you have just created, click on the down arrow ( ) above the icon. The following equations will appear:

Plastics_in_Landfills(t) = Plastics_in_Landfills(t - dt) + dumping * dt

INIT Plastics_in_Landfills = 0

DOCUMENT: Initially the landfill is empty

UNITS: gallons of plastics

dumping = 5000 * 365

DOCUMENT: Citizens in Boise will dump 5,000 gallons of plastics into the landfill every day for the 365 days that make up a year.

UNITS: gallons of plastics/year

? Click on the up arrow () to return to the model construction level.

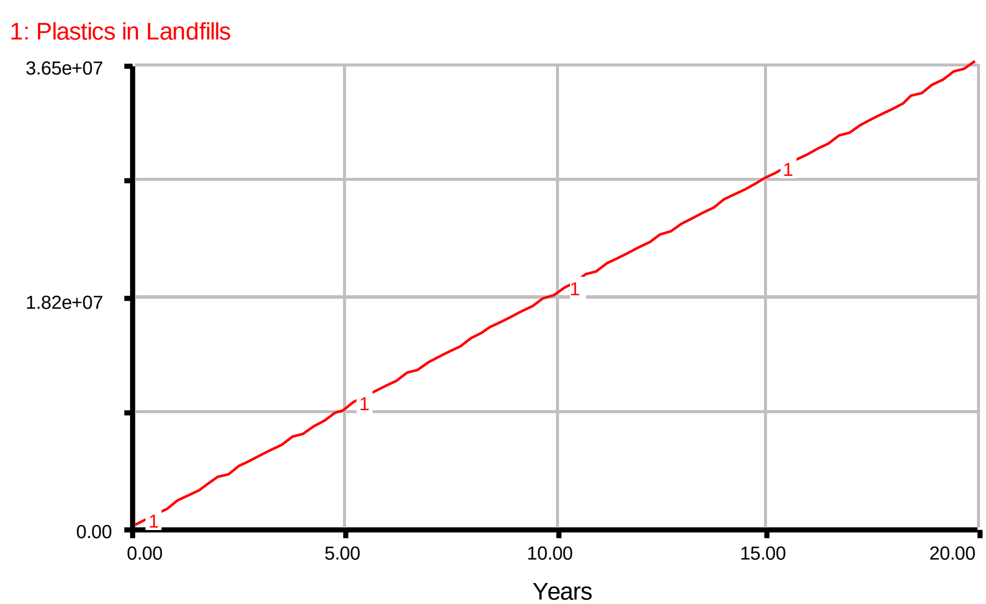
? Double-click on the graph icon () if the graph pad is no longer in view. Notice that the graph was erased when you used the dynamite to blow up the skunk population model.

? Double-click on the graph pad itself to open it. When the dialog box opens, name the graph "Landfills." Double-click on “Plastics in Landfills” from the Allowable Inputs list to select it to be graphed. Click OK.

? Select Time Specs in the Run menu. “Years” should already be selected. Set the Range values from 0 to 20. Click OK.

? To run the graph, either select Run from the Run menu, hold down both open-apple (⌘) and “R,” or click on the little runner to bring up the run controller window and click on the play button.

You will see the graph displayed below:



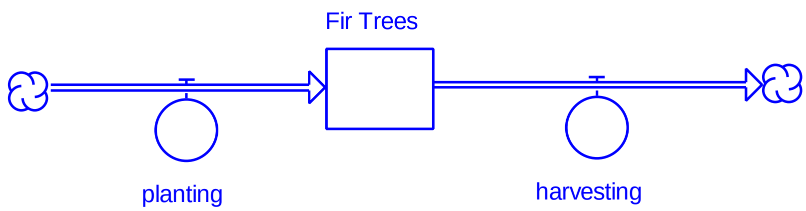
From the graph you can answer our question by translating 3.65e+07 from scientific notation (by multiplying 3.65 by 10^7): in 20 years, the landfill outside of Boise will contain 36 and a half million gallons of plastics.

4.3 Fir Trees

Scenario: Today, approximately five million fir trees stand tall in Hardwood Forest. A lumber company has been cutting down, harvesting, approximately one hundred thousand trees every year. An environmental group, worried that the forest will be entirely destroyed, has been working hard to plant as many new fir trees as possible. They have been able to plant approximately five thousand trees every year.

Question: How many fir trees will there be in Hardwood Forest in thirty years?

Answer: 2 million 150 thousand fir trees



□**Fir_Trees**(t) = Fir_Trees(t - dt) + (planting - harvesting) * dt

INIT Fir_Trees = 5e6

DOCUMENT: The initial number of fir trees is 5 million (or 5,000,000 or 5e6)

UNITS: fir trees

planting = 5000

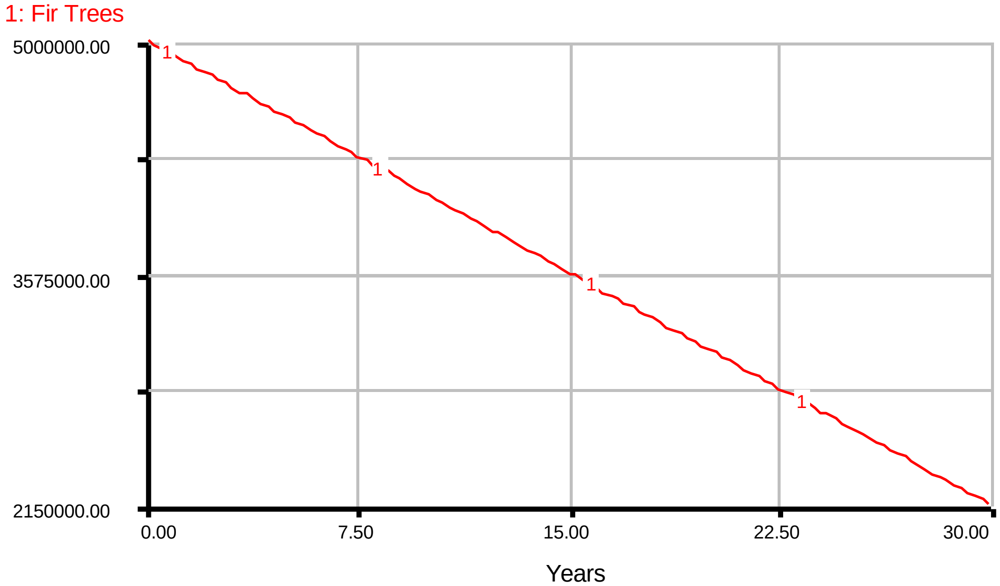
DOCUMENT: an environmental group plants 5000 trees every year

UNITS: fir trees/year

harvesting = 1e5

DOCUMENT: a lumber company harvests 100,000 trees every year (or 1e5)

UNITS: fir trees/year

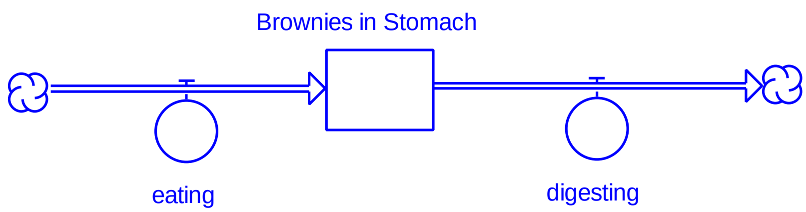

1: Fir Trees
5000000.00
3575000.00
2150000.00
0.00
7.50
15.00
22.50
30.00
Years

4.4 Brownies

Scenario: It's Saturday and Mathilda is working alone at home on a group project. Mathilda's best friend feels guilty that she's not contributing to the team effort, so she bakes Mathilda an enormous plate of brownies that she brings over with many words of encouragement. Mathilda nibbles on the brownies as she works. She eats a brownie every hour. As Mathilda works on the group project, her stomach works on digesting the brownies. Mathilda digests a brownie every two hours.

Question: Eight hours later, when Mathilda finishes her work on the group project, how many brownies does she have in her stomach?

Answer: 4 brownies



□ **Brownies_in_Stomach**(t) = Brownies_in_Stomach (t - dt) + (eating - digesting) * dt

INIT Brownies_in_Stomach = 0

DOCUMENT: Initially Mathilda's stomach is empty.

UNITS: brownies

eating = 1

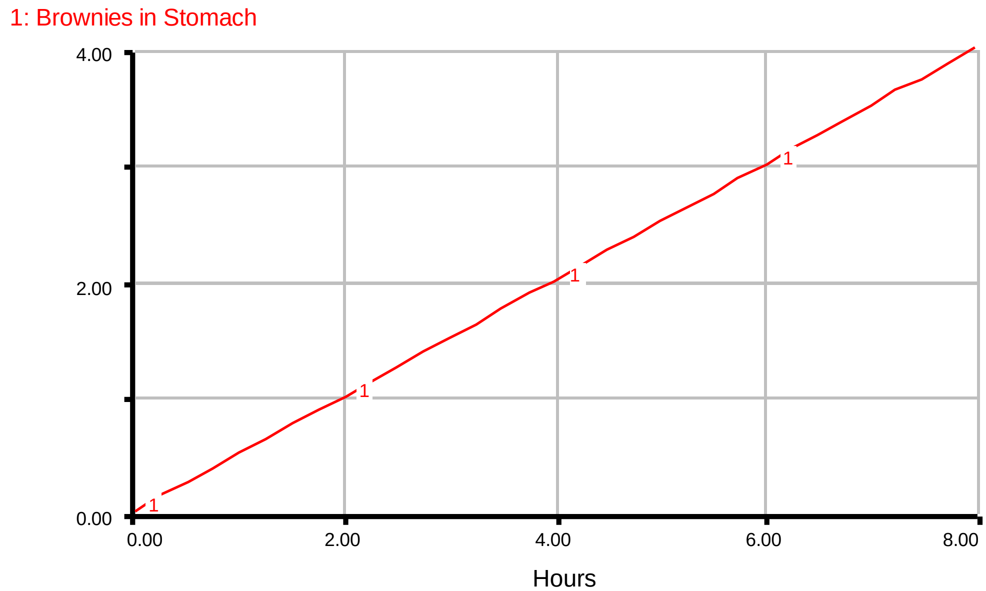
DOCUMENT: Mathilda eats a brownie every hour.

UNITS: brownies/hour

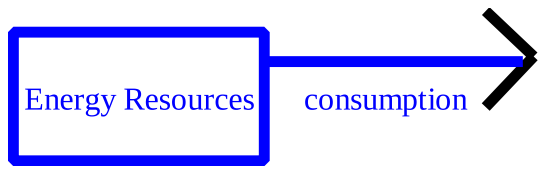
digesting = 1/2

DOCUMENT: Mathilda digests 1 brownie every 2 hours. She therefore digests a half a brownie every hour.

UNITS: brownies/hour


1: Brownies in Stomach
4.00
2.00
0.00
0.00
2.00
4.00
6.00
8.00
Hours
1
1
1
1

4.5 Energy Resources

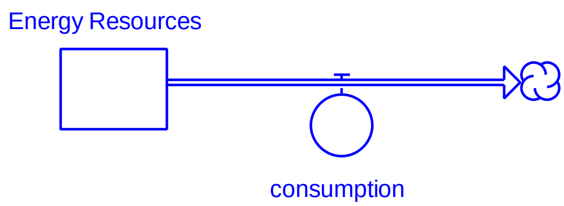


Scenario: In 1972 the world's known reserves of chromium were about 775 million metric tons, of which about 1.85 million metric tons are milled annually at present.[1] Make the temporary assumption that the world population is not growing and industrializing, increasing the demand for chromium exponentially, but instead is at some (unrealistic) equilibrium so that the demand for chromium is constant.

Question: At the current rate of consumption, approximately how long will the known reserves last? (Hint: Try running the model several times, increasing or decreasing the time scale, until you find the numbers of years after which the chromium reserves drop to zero.)

[1] Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William W. Behrens III, 1972. <u>The Limits to Growth</u>. New York, NY; Universe Books, p. 61.

Answer: 420 years



☐**Energy_Resources**(t) = Energy_Resources (t - dt) - consumption * dt

INIT Energy_Resources = 7.75e8

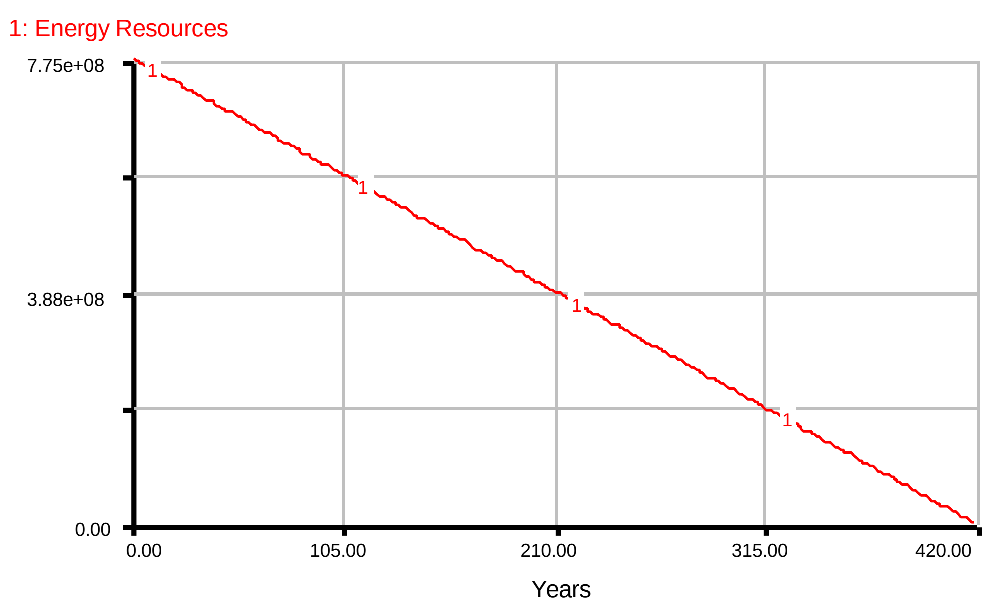
DOCUMENT: In 1972 the world's known reserves of chromium were about 775 million metric tons.

UNITS: metric tons

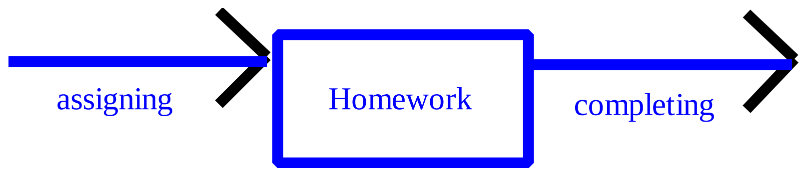
consumption = 1.85e6

DOCUMENT: 1.85 million metric tons are milled annually at present.

UNITS: metric tons/hour



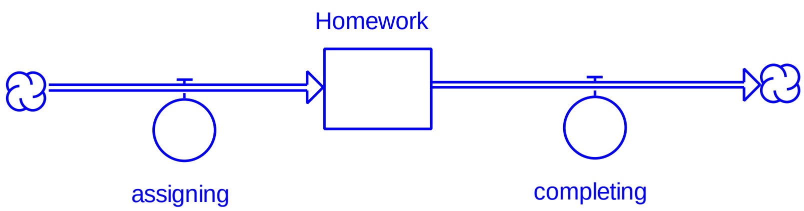
4.6 Homework



Scenario: Mathilda, the ever-studious student, diligently does her homework. Corky, on the other hand, is a slacker. He lets his work build up. Every week he receives seven new assignments. Over the course of the week he completes one or two of the assignments. (On average, he completes one and a half). The semester is twelve weeks long.

Question: How many assignments does Corky have to do at the end of the semester, right before his final exams?

Answer: 66 assignments



□ **Homework** (t) = Homework (t - dt) + (assigning - completing) * dt

INIT Homework = 0

DOCUMENT: Corky begins the year on a clean slate.

UNITS: assignments

assigning = 7

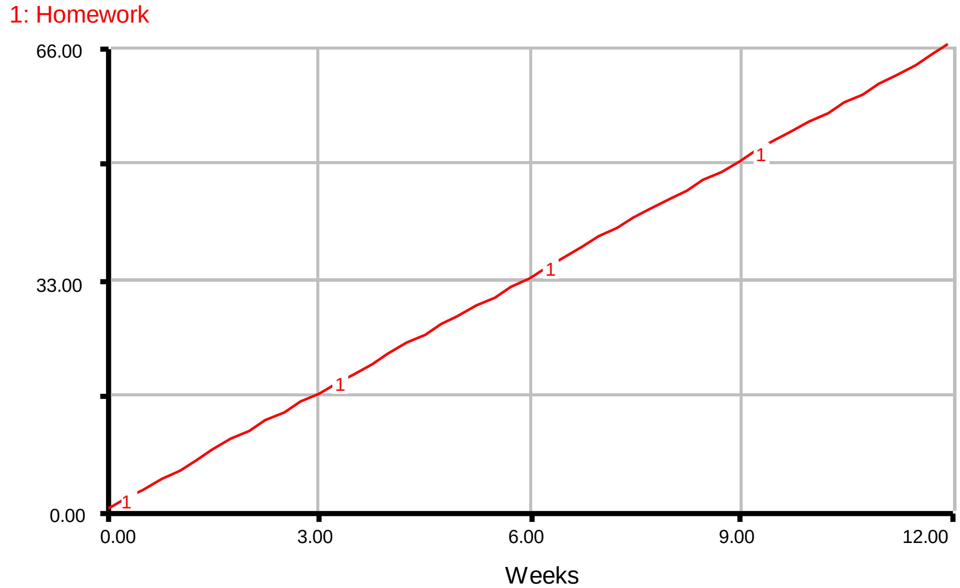
DOCUMENT: Every week Corky receives 7 new assignments.

UNITS: assignments/week

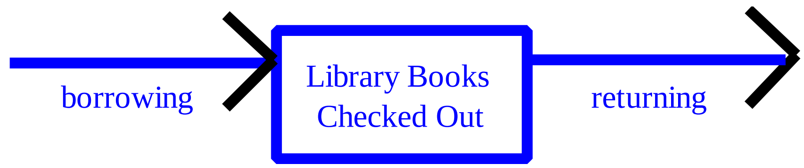
completing = 1.5

DOCUMENT: Over the course of the week Corky completes one or two of his assignments, so on average he completes one and a half assignments.

UNITS: assignments/week


1: Homework
66.00
33.00
0.00
0.00
3.00
6.00
9.00
12.00
Weeks
1
1
1
1

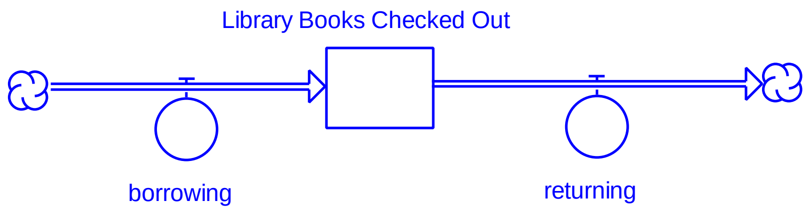
4.7 Library Books



Scenario: Laughton has a pile of five library books on the floor next to his desk. He loves to read. Every week Laughton returns four of the books that he has read. He also checks out four new books.

Question: How large is Laughton's pile of library books after eight weeks?

Answer: 5 books



Library_Books_Checked_Out (t) = Library_Books_Checked_Out (t - dt) + (borrowing - returning) * dt

INIT Library_Books_Checked_Out = 5

DOCUMENT: Laughton has a pile of 5 library books on the floor next to his desk.

UNITS: books

borrowing = 4

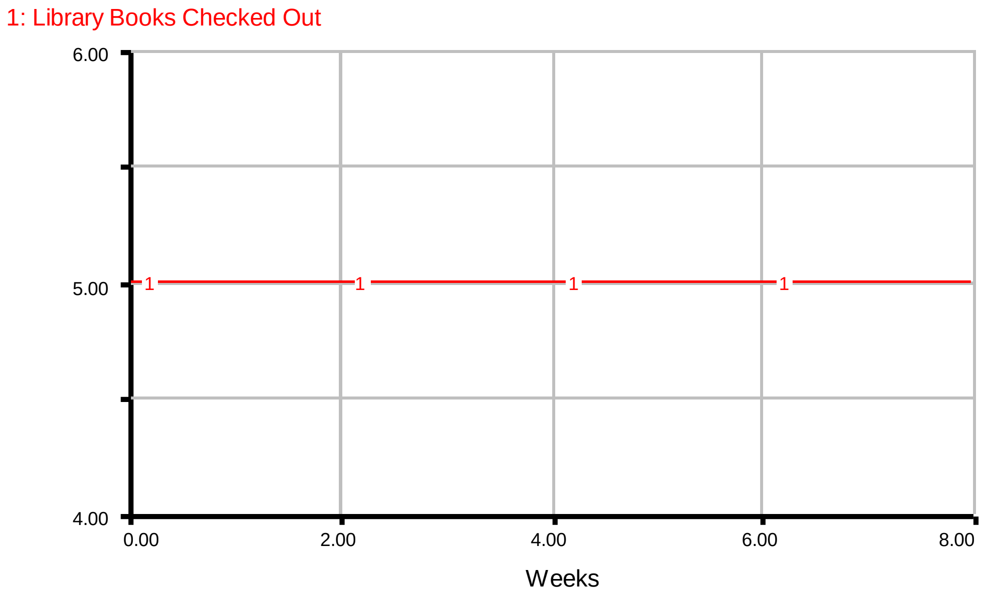
DOCUMENT: Every week Laughton checks out 4 new books.

UNITS: books/week

returning = 4

DOCUMENT: Laughton returns 4 library books every week.

UNITS: books/week

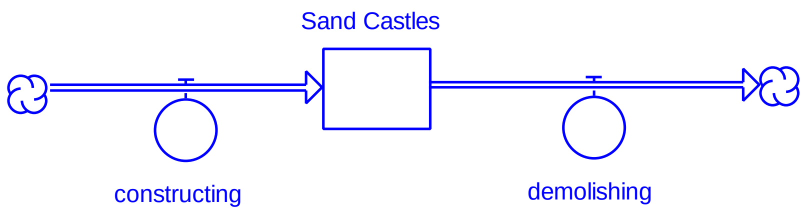

1: Library Books Checked Out
6.00
5.00
4.00
1
0.00
2.00
4.00
6.00
8.00
Weeks

4.8 Sand Castles

Scenario: A beach club in St. Tropez is organized a sand castle contest. At 10 AM, eighty children gathered on the beach to make their sand castles. Unfortunately, at that time the tide was on the rise. Each child was able to build a new sand castle every hour. The incoming tide and the advancing waves demolished fifty sand castles every hour.

Question: How many sand castles were left on the beach at 6 PM? (Hint: you can either run your simulation from 10:00 to 18:00 or from 0 to 8 hours after the beginning of the contest)

Answer: 240 sand castles



□ **Sand_Castles** (t) = Sand_Castles (t - dt) + (constructing - demolishing) * dt

INIT Sand_Castles = 0

DOCUMENT: When the children arrive the sandy beach is barren.

UNITS: castles

constructing = 80

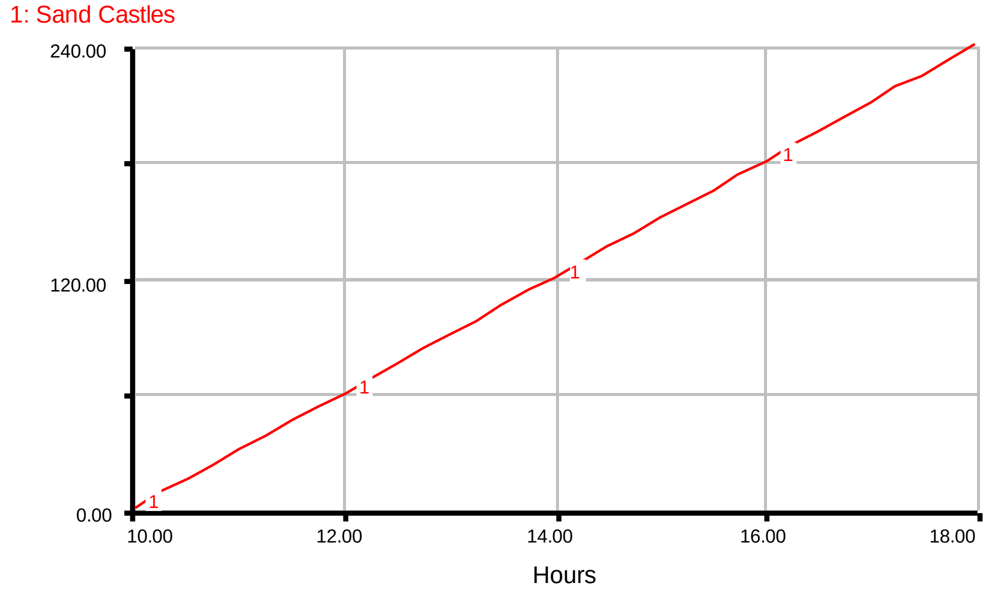
DOCUMENT: Each of the 80 children builds a new sand castle every hour.

UNITS: castles/hour

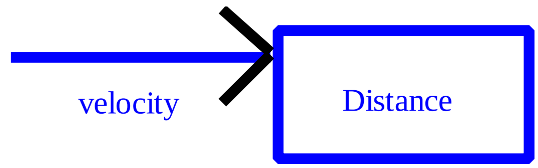
demolishing = 50

DOCUMENT: The advancing waves demolished 50 sand castles every hour.

UNITS: castles/hour


1: Sand Castles
240.00
120.00
0.00
1
1
1
1
10.00
12.00
14.00
16.00
18.00
Hours

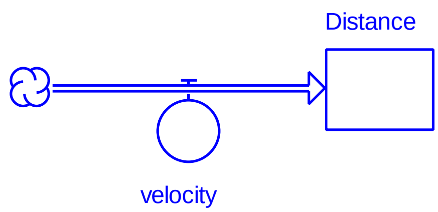
4.9 Distance



Scenario: Randy is training to run in the Boston Marathon. If he paces himself, he can run eight minute miles. Randy likes to run in the morning, before breakfast. He wakes up at 7 AM, and eats breakfast at 8 AM.

Question: How many miles can Randy run before breakfast? (Hint: you can run the simulation from 7 to 8 hours or for 60 minutes. It does not matter which units you choose, but you *must* be consistent and use *either* minutes *or* hours throughout.)

Answer: 7.5 miles



☐ **Distance**(t) = Distance (t - dt) + velocity * dt

INIT Distance = 0

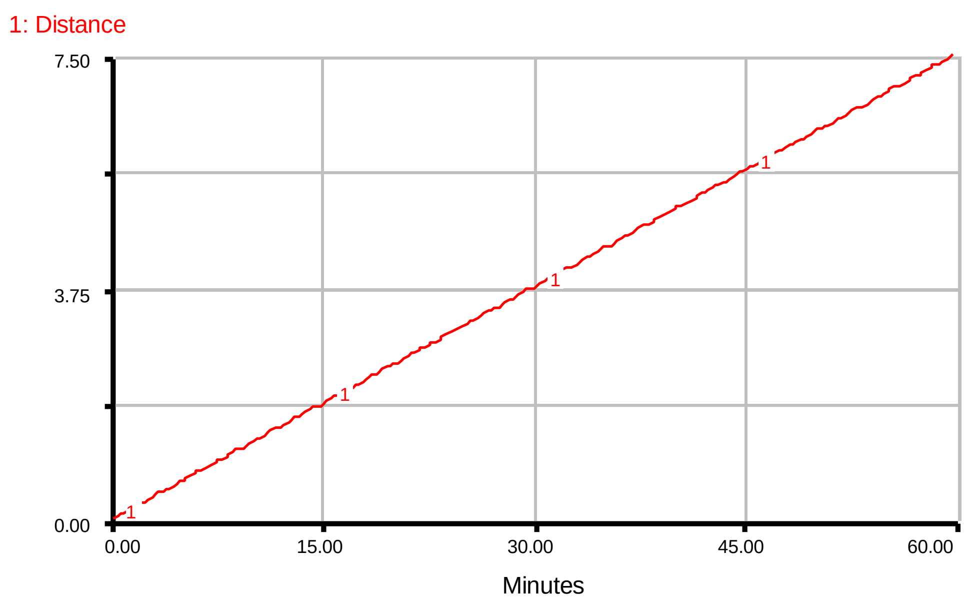
DOCUMENT: At 7 AM Randy has not run any miles yet.

UNITS: miles

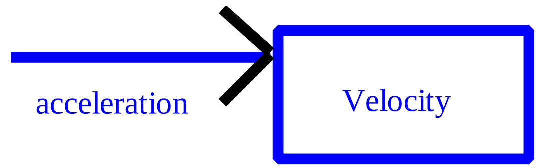
velocity = 1 / 8

DOCUMENT: Because Randy can run 1 mile in 8 minutes, he can run 1/8 of a mile in one minute.

UNITS: miles/minute



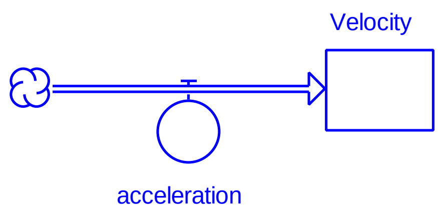
4.10 Velocity



Scenario: A Ferrari is paused at a red light. The light turns green. The driver slams down the accelerator and the sports car springs forward. He keeps his foot tight on the accelerator. The car accelerates at five miles per hour per second.

Question: How fast will the Ferrari be cruising sixteen seconds later?

Answer: 80 miles per hour



□ **Velocity**(t) = Velocity (t - dt) + acceleration * dt

INIT Distance = 0

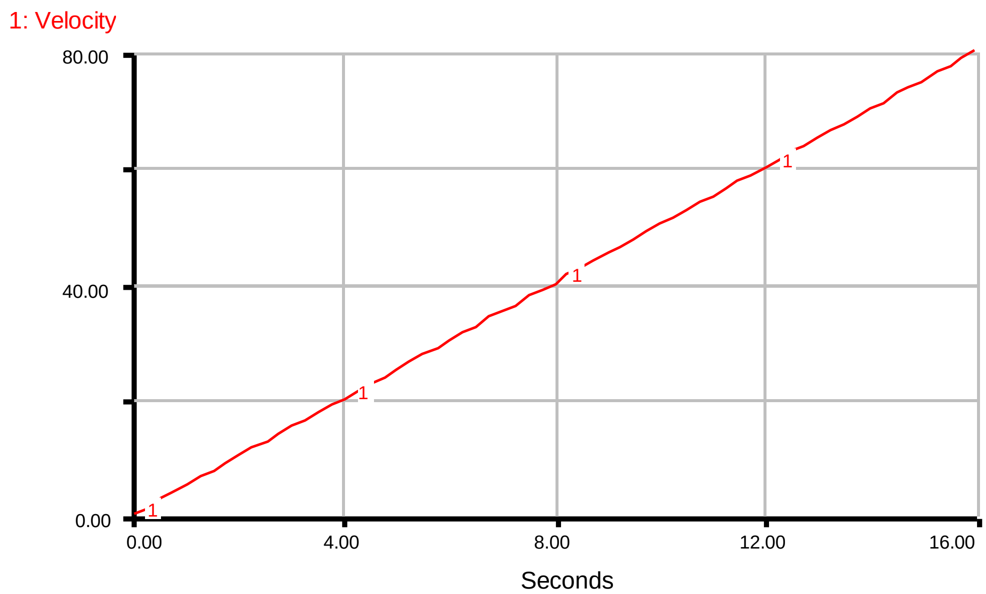
DOCUMENT: At the red light the car is stopped, so its velocity is 0.

UNITS: miles per hour

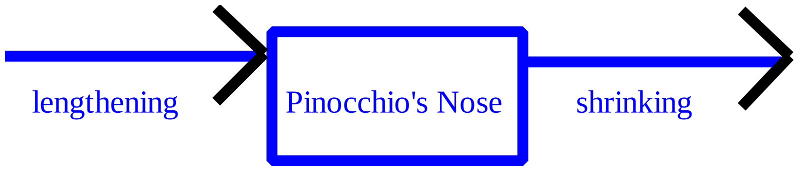
acceleration = 5

DOCUMENT: The car accelerates at 5 miles per hour/second.

UNITS: miles per hour /second



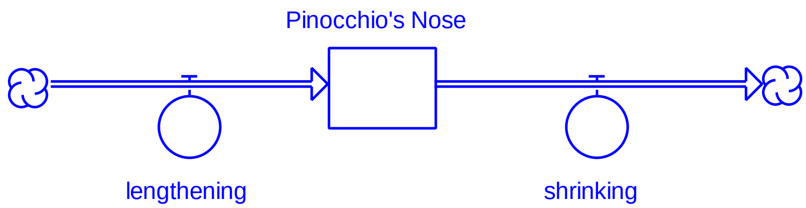
4.11 Pinocchio



Scenario: When Pinocchio lies his nose lengthens by one centimeter. Each time he does a good dead, his nose shrinks five centimeters. Every day, Pinocchio tells an average of 8 lies and performs, on average, one good deed.

Question: If Monday morning Pinocchio's nose is 4 centimeters long, how long will his nose be on Saturday night?

Answer: 22 centimeters



☐ **Pinocchio's_Nose** (t) = Pinocchio's_Nose (t - dt) + (lengthening - shrinking) * dt

INIT Pinocchio's_Nose = 4

DOCUMENT: On Monday morning Pinocchio's nose is 4 centimeters long.

UNITS: centimeters

lengthening = 8

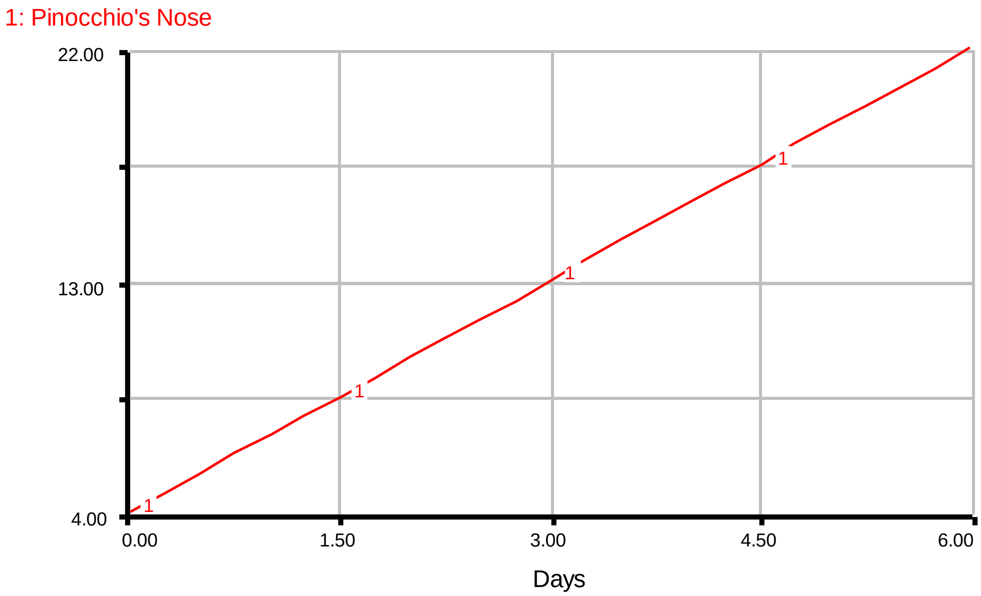
DOCUMENT: Pinocchio tells 8 lies each day and his nose lengthens 1 centimeter for each lie.

UNITS: centimeters/day

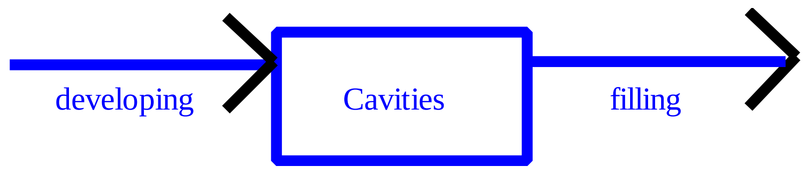
shrinking = 5

DOCUMENT: Pinocchio performs 1 good deed each day and his nose shrinks 5 centimeters for that good deed.

UNITS: centimeters/day


1: Pinocchio's Nose
22.00
13.00
4.00
0.00
1.50
3.00
4.50
6.00
Days

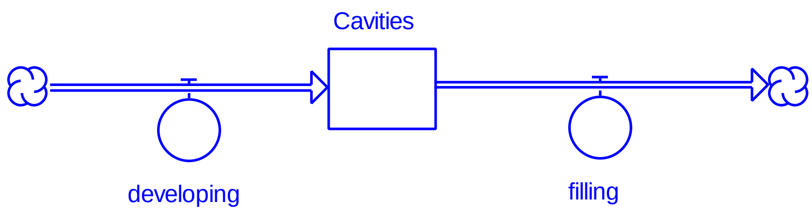
4.12 Cavities



Scenario: I develop a full-blown cavity every two years. I do not go to see my dentist very often; I get a cavity filled every three years. Because I wait so long the process is often quite painful.

Question: I currently don't have any cavities. How many will I have in 15 years?

Answer: 2 and a half cavities



☐ **Cavities** (t) = Cavities (t - dt) + (developing - filling) * dt

INIT Cavities = 0

DOCUMENT: I currently don't have any cavities.

UNITS: cavities

developing = 1/2

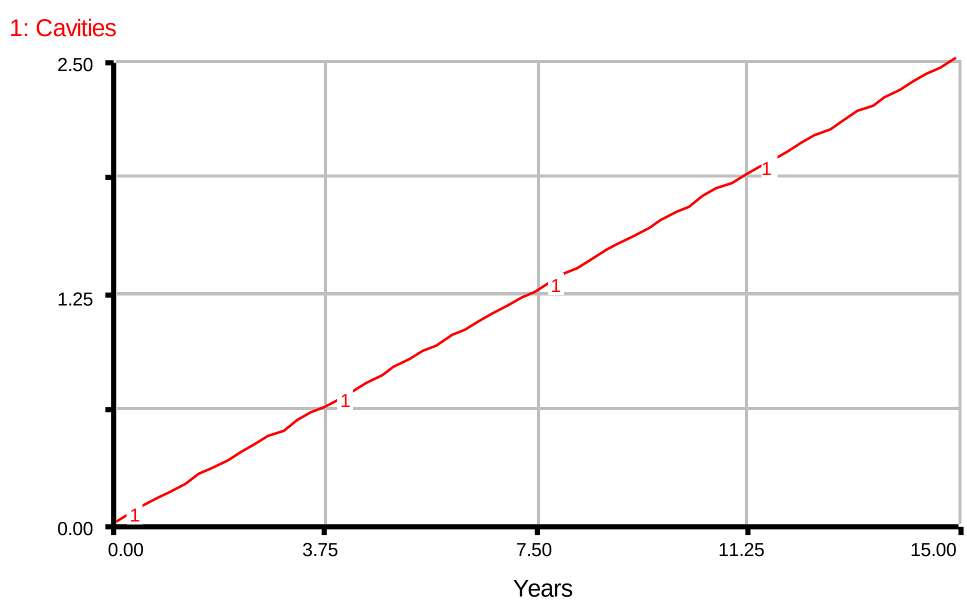
DOCUMENT: I develop a full-blown cavity every two years.

UNITS: cavities/year

filling = 1/3

DOCUMENT: I get a cavity filled every three years.

UNITS: cavities/year

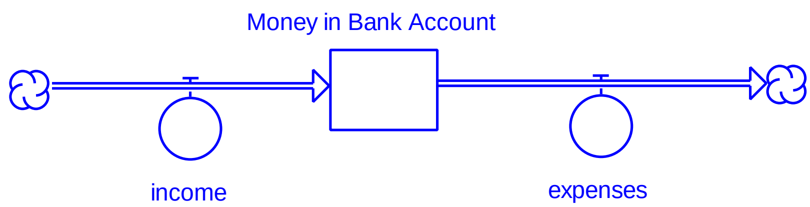


4.13 A Bank Account

Scenario: Stephanie has $678.53 in her bank account. Every week she earns $120. Each week $23.70 are deducted from her paycheck for social security, Medicare, local, state, and federal taxes. She spends $7.75 every week to go out for a movie and approximately $60 every three weeks on clothes.

Question: How much money will Stephanie have in her bank account in four months (sixteen weeks from now)?

Answer: 1775.33 dollars



☐ **Money_in_Bank_Account** (t) = Money_in_Bank_Account (t - dt) + (income - expenses) * dt

INIT Money_in_Bank_Account = 678.53

DOCUMENT: Stephanie has $678.53 in her bank account.

UNITS: dollars

income = 120 - 23.7

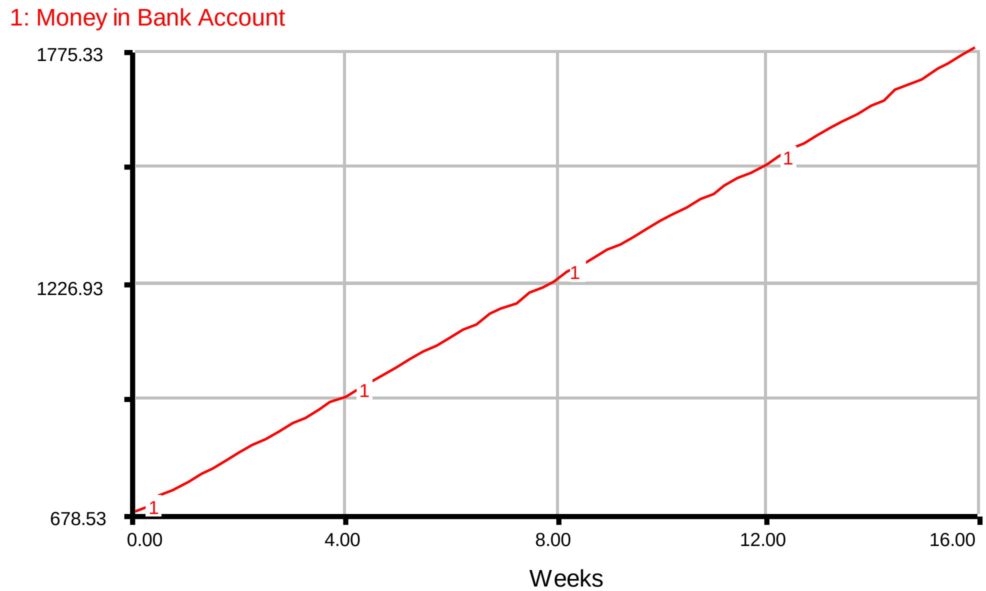
DOCUMENT: Every week she gets a paycheck for $120 minus $23.70 in taxes.

UNITS: dollars/week

expenses = 7.75 + 60 / 3

DOCUMENT: She spends $7.75 every week on a movie and $60 every three weeks on clothes.

UNITS: dollars/week

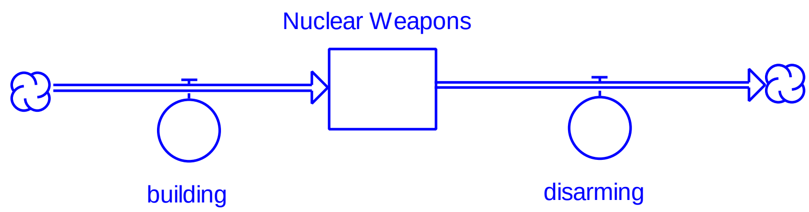

1: Money in Bank Account
1775.33
1226.93
678.53
0.00
4.00
8.00
12.00
16.00
Weeks
1
1
1
1

4.14 Nuclear Weapons

Scenario: In 1990 the fictional country of Euromerica had an arsenal of approximately ten thousand nuclear weapons. Every year, scientists and engineers design and manufacture five hundred new nuclear weapons. Because of an international pressure in favor of disarmament, Euromerica disarms approximately six hundred of its older nuclear weapons each year.

Question: If Euromerica continues at its current rates of building and disarming, how many nuclear weapons will the nuclear arsenal contain in the year 2010?

Answer: 8000 nuclear weapons



□**Nuclear_Weapons**(t) = Nuclear_Weapons(t - dt) + (building - disarming) * dt

INIT Nuclear_Weapons = 10000

DOCUMENT: In 1990 Euromerica has 10,000 nuclear weapons.

UNITS: weapons

building = 500

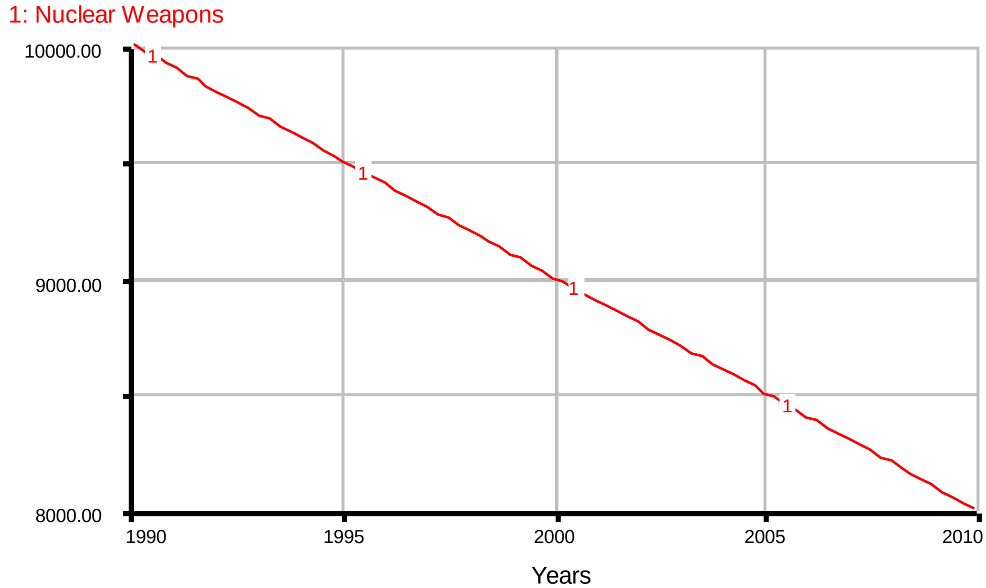
DOCUMENT: Every year Euromerica builds 500 new nuclear weapons.

UNITS: weapons/year

disarming = 600

DOCUMENT: Every year Euromerica disarms 600 nuclear weapons.

UNITS: weapons/year


1: Nuclear Weapons
10000.00
9000.00
8000.00
1990
1995
2000
2005
2010
Years

Vensim Examples:
Beginner Modeling Exercises

By Lei Lei and Nathaniel Choge

October 2001

Section 4.1: Skunks

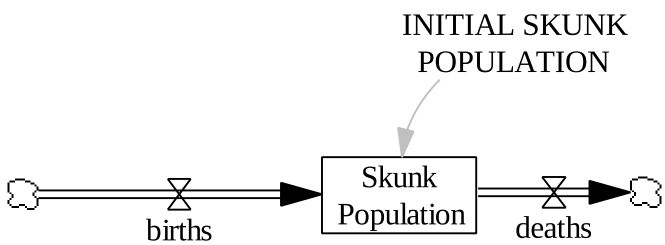


Figure 1: Vensim Equivalent of Skunks model

Documentation for Skunks Model:

(1) births = 100

Units: skunks/Year

100 baby skunks are born every year.

(2) deaths = 120

Units: skunks/Year

120 skunks die every year.

(3) FINAL TIME = 10

Units: Year

The final time for the simulation.

(4) INITIAL SKUNK POPULATION = 500

Units: skunks

The initial skunk population is 500 skunks.

(5) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(6) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(7) Skunk Population= INTEG (births-deaths, INITIAL SKUNK POPULATION)

Units: skunks

The skunk population.

(8) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

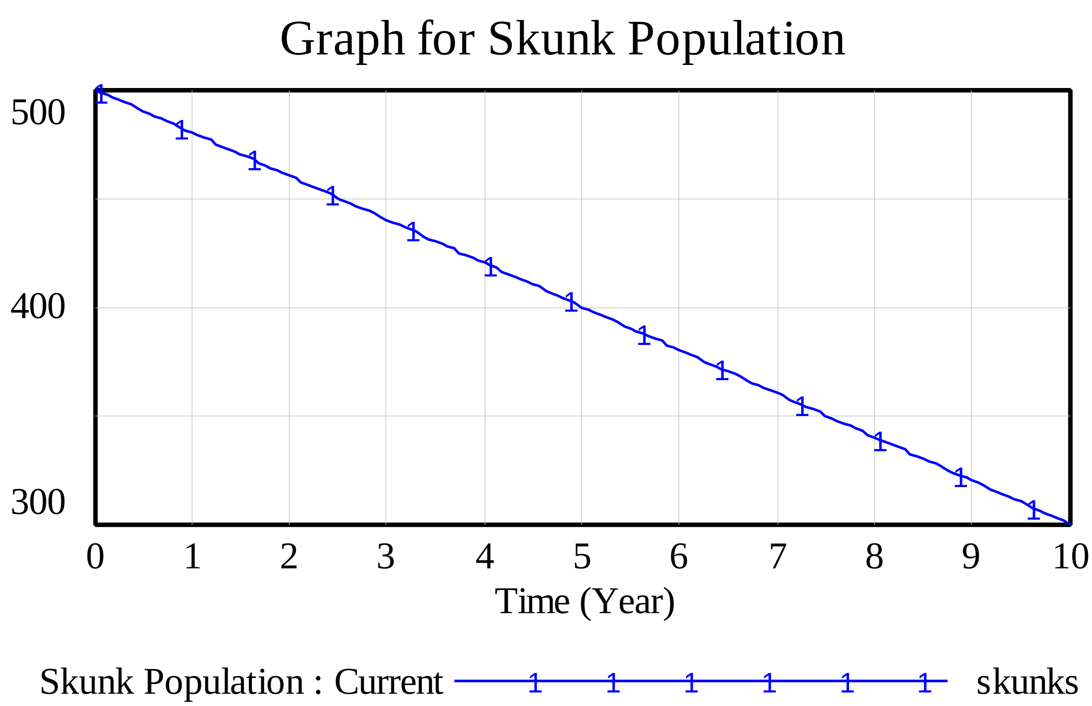


Figure 2: Vensim Equivalent of Simulation for Number of Skunks

Section 4.2: Landfills

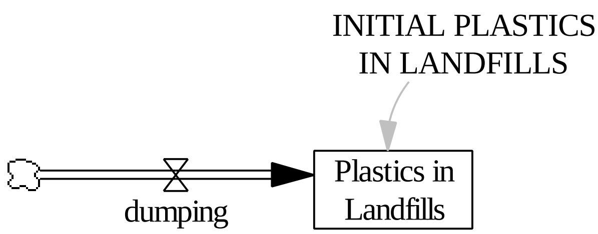


Figure 3: Vensim Equivalent of Landfills

Documentation for Landfills Model:

(1) dumping = 5000*365

Units: gallons of plastics/Year

Citizens in Boise will dump 5,000 gallons of plastics into the landfill for the 365 days that make up the year.

(2) FINAL TIME = 20

Units: Year

The final time for the simulation.

(3) INITIAL PLASTICS IN LANDFILLS = 0

Units: plastics

Initially the landfill is empty.

(4) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(5) Plastics in Landfills= INTEG (dumping, INITIAL PLASTICS IN LANDFILLS)

Units: gallons of plastics

Gallons of plastics in the landfill.

(6) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(7) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

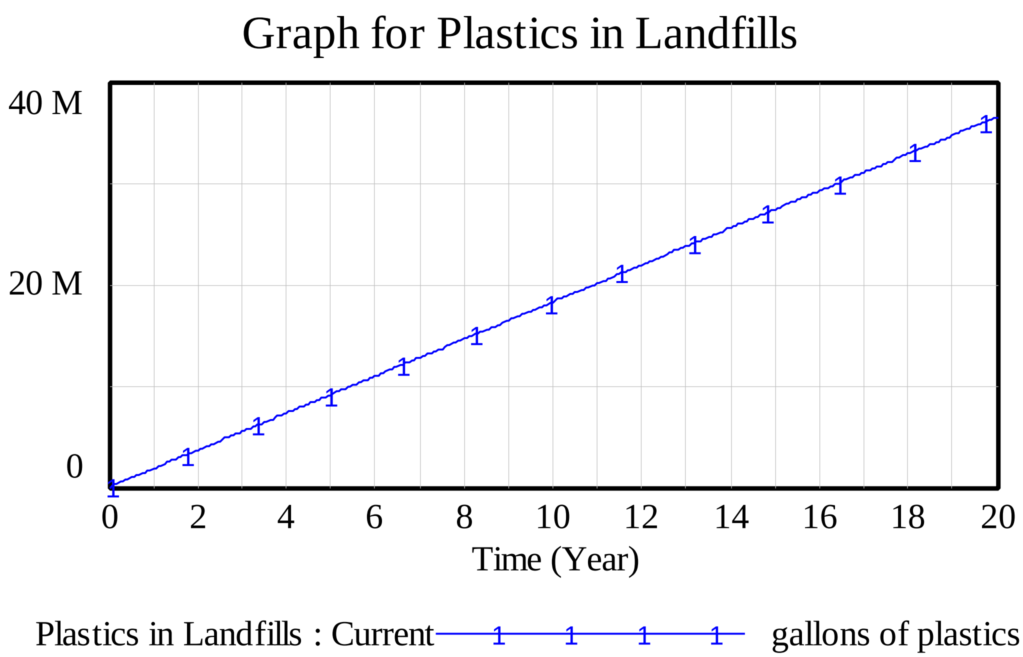


Figure 4: Vensim Equivalent of Simulation for plastics in landfills

Section 4.3: Fir Trees

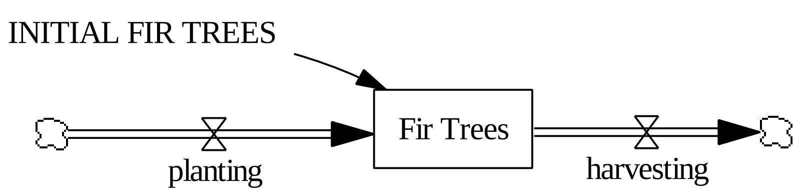


Figure 5: Vensim Equivalent of Fir Trees

Documentation for Fir Trees model:

(1) FINAL TIME = 30

Units: Year

The final time for the simulation.

(2) Fir Trees = INTEG (+planting-harvesting, INITIAL FIR TREES)

Units: fir trees

(3) harvesting = 100000

Units: fir trees/Year

A lumber company harvests 100,000 trees every year.

(4) INITIAL FIR TREES = 5e+006

Units: fir trees

(5) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(7) planting = 5000

Units: fir trees/Year

An environmental group plants 5000 trees every year.

(8) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(9) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

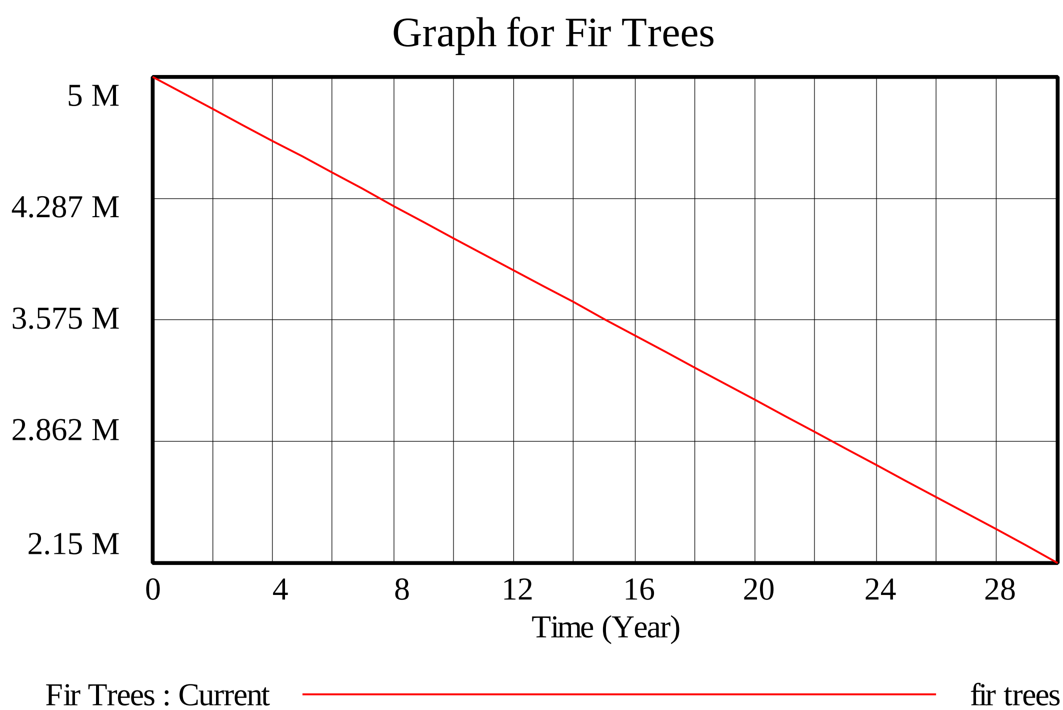


Figure 6: Vensim Equivalent of Simulation for Number of Fir Trees

Section 4.4: Brownies

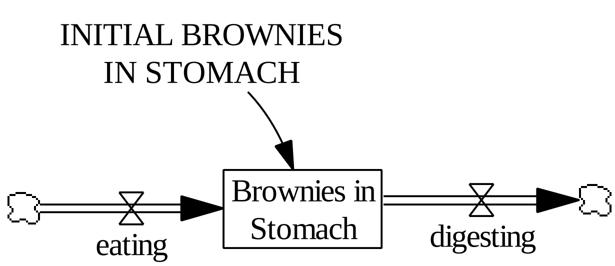


Figure 7: Vensim Equivalent of Brownies Model

Documentation for Brownies Model:

(1) Brownies in Stomach = INTEG (+eating-digesting, INITIAL BROWNIES IN STOMACH)

Units: brownies

Initially Mathilda's stomach is empty.

(2) digesting = 0.5

Units: brownies/hour

Mathilda digests 1 brownie every 2 hours. She therefore digests a half a brownies every hour.

(3) eating = 1

Units: brownies/hour

Mathilda eats a brownie every hour.

(4) FINAL TIME = 100

Units: Month

The final time for the simulation.

(5) INITIAL BROWNIES IN STOMACH = 0

Units: brownies

(6) INITIAL TIME = 0

Units: Month

The initial time for the simulation.

(7) SAVEPER = 1

Units: Month

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Month

The time step for the simulation.

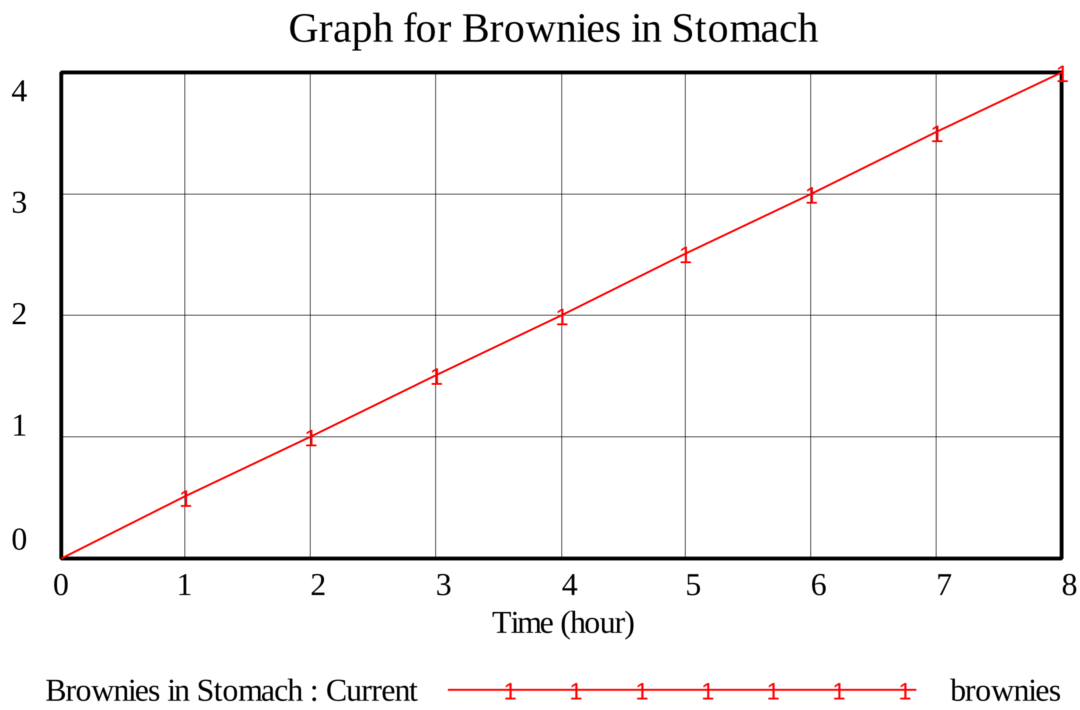


Figure 8: Vensim Equivalent of Simulation for Number of Brownies

Section 4.5: Energy Resources

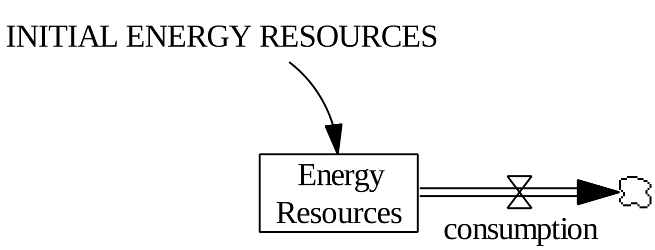


Figure 9: Vensim Equivalent of Energy Resources Model

Documentation for Energy Resources Model:

(1) consumption = 1.85e+006

Units: metric tons/hour

1.85 million metric tons are milled annually at present.

(2) Energy Resources = INTEG (-consumption, INITIAL ENERGY RESOURCES)

Units: metric tons

In 1972 the world's known reserves of chromium were about 775 million metric tons.

(3) FINAL TIME = 420

Units: Year

The final time for the simulation.

(4) INITIAL ENERGY RESOURCES = 7.75e+008

Units: metric tons

(5) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(6) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(7) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

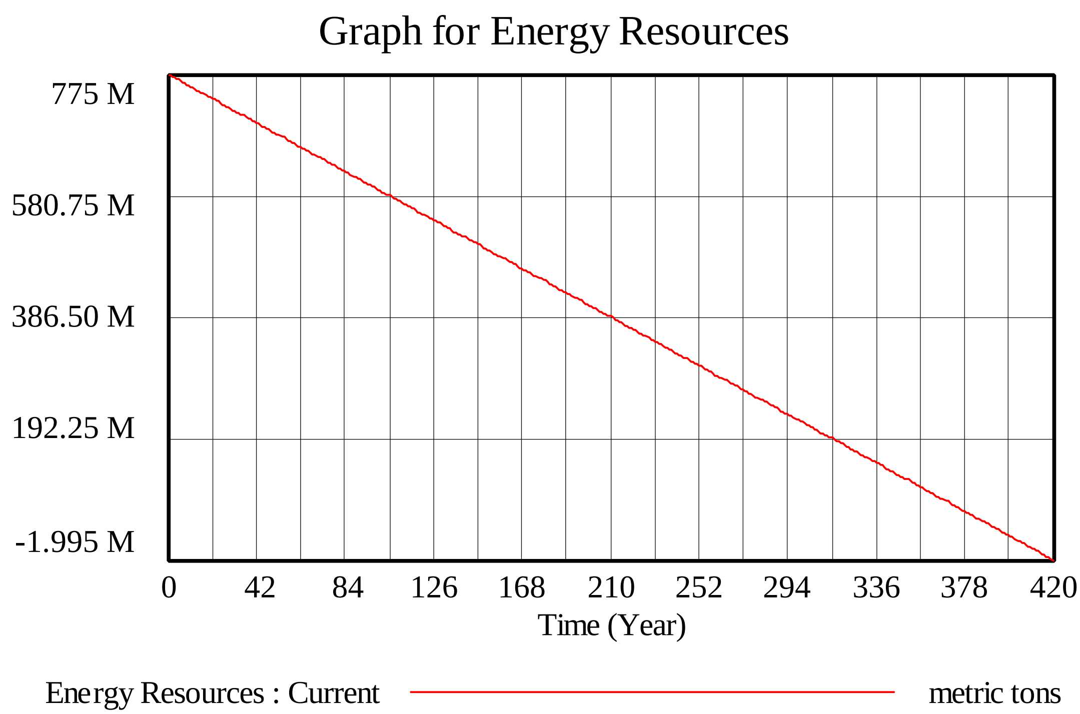


Figure 10: Vensim Equivalent of Simulation of Amount of Energy Resources

Section 4.6: Homework

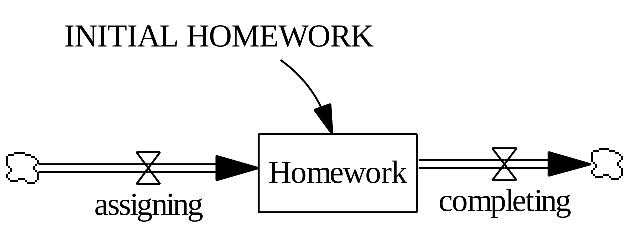


Figure 11: Vensim Equivalent of Homework Model

Documentation for Homework Model:

(1) assigning = 7

Units: assignments/Week

Every week Corky receives 7 new assignments.

(2) completing = 1.5

Units: assignments/Week

Over the course of the week Corky completes one or two of his assignments, so on average he completes one and a half assignments.

(3) FINAL TIME = 12

Units: Week

The final time for the simulation.

(4) Homework = INTEG (assigning-completing, INITIAL HOMEWORK)

Units: assignments

Corky begins the year on a clean slate.

(5) INITIAL HOMEWORK = 0

Units: assignments

(6) INITIAL TIME = 0

Units: Week

The initial time for the simulation.

(7) SAVEPER = TIME STEP

Units: Week

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Week

The time step for the simulation.

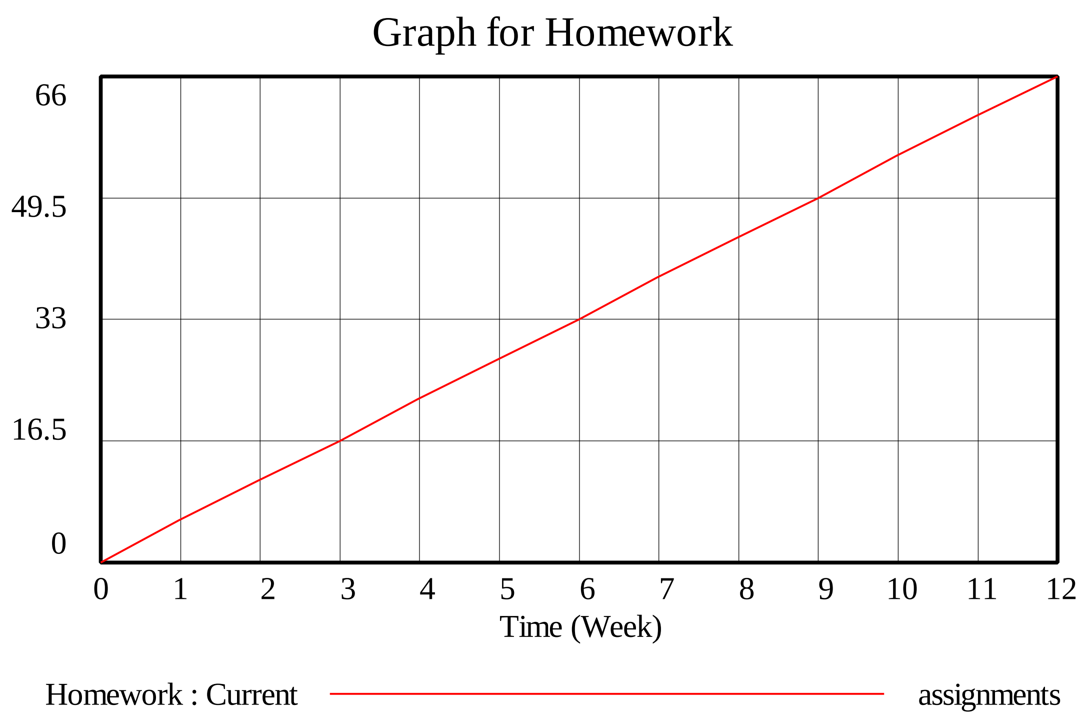


Figure 12: Vensim Equivalent of Simulation for Number Homework

Section 4.7: Library Books

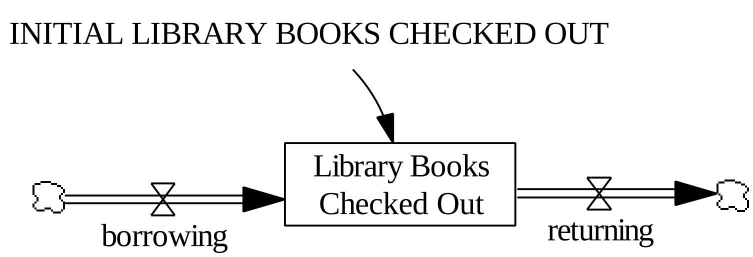


Figure 13: Vensim Equivalent of Library Books Model

Documentation for Library Books Model:

(1) borrowing = 4

Units: books/Week

Every week Laughton checks out 4 new books.

(2) FINAL TIME = 8

Units: Week

The final time for the simulation.

(3) INITIAL TIME = 0

Units: Week

The initial time for the simulation.

(4) INITIAL LIBRARY BOOKS CHECKED OUT = 5

Units: books

(5) Library Books Checked Out = INTEG (borrowing-returning, INITIAL LIBRARY BOOKS CHECKED OUT)

Units: books

Laughton has a pile of 5 library books on the floor next to his desk.

(6) returning = 4

Units: books/Week

Laughton returns 4 library books every week.

(7) SAVEPER = TIME STEP

Units: Week

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Week

The time step for the simulation.

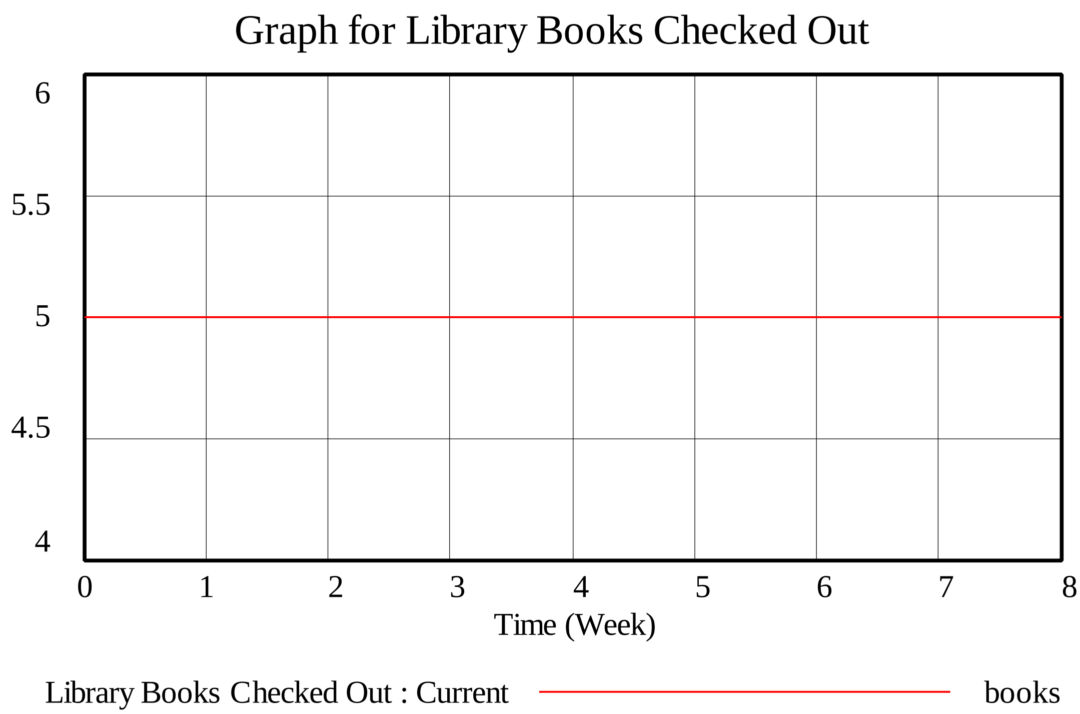


Figure 14: Vensim Equivalent of Simulation for Number of Library Books

Section 4.8: Sand Castle

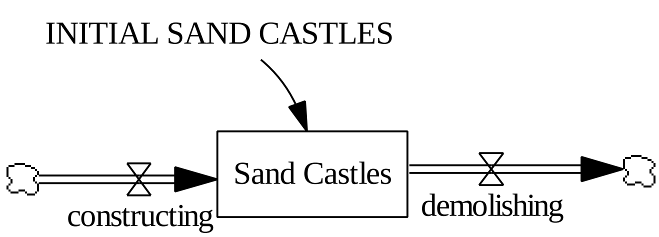


Figure 15: Vensim Equivalent of Sand Castle Model

Documentation for Sand Castle Model:

(1) constructing = 80

Units: castles/Hour

Each of the 80 children builds a new sand castle every hour.

(2) demolishing = 50

Units: castles/Hour

The advancing waves demolished 50 sand castles every hour.

(3) FINAL TIME = 18

Units: Hour

The final time for the simulation.

(4) INITIAL SAND CASTLES = 0

Units: castles

(5) INITIAL TIME = 0

Units: Hour

The initial time for the simulation.

(6) Sand Castles = INTEG (constructing-demolishing, INITIAL SAND CASTLES)

Units: castles

When the children arrive the sandy beach is barren.

(7) SAVEPER = TIME STEP

Units: Hour

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Hour

The time step for the simulation.

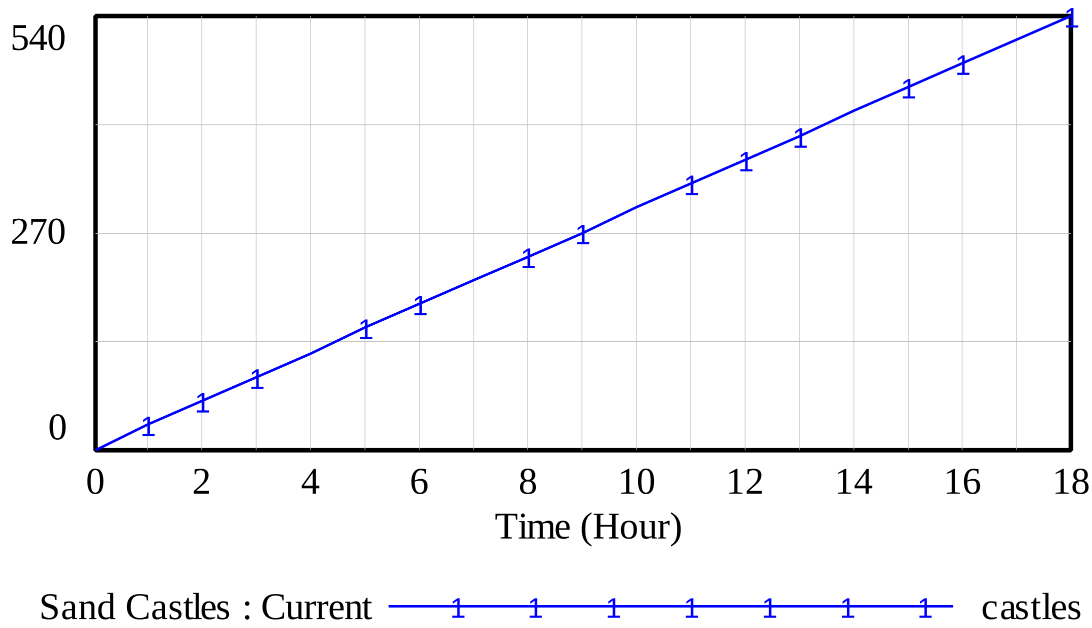


Figure 16: Vensim Equivalent of Simulation of Number of Sand Castles

Section 4.9: Distance

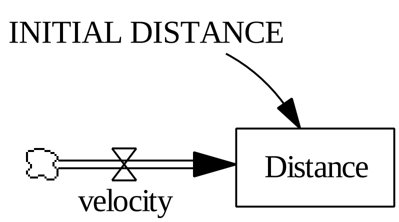


Figure 17: Distance Model

Documentation for Distance Model:

(1) Distance = INTEG (velocity, INITIAL DISTANCE)

Units: miles

At 7AM Randy has not run any miles yet.

(2) FINAL TIME = 60

Units: Minute

The final time for the simulation.

(3) INITIAL DISTANCE = 0

Units: minute

(4) INITIAL TIME = 0

Units: Minute

The initial time for the simulation.

(5) SAVEPER = TIME STEP

Units: Minute

The frequency with which output is stored.

(6) TIME STEP = 0.0625

Units: Minute

The time step for the simulation.

(7) velocity = 0.125

Units: miles/Minute

Because Randy can run 1 mile in 8 minutes, he can run 0.125 of a mile in one minute.

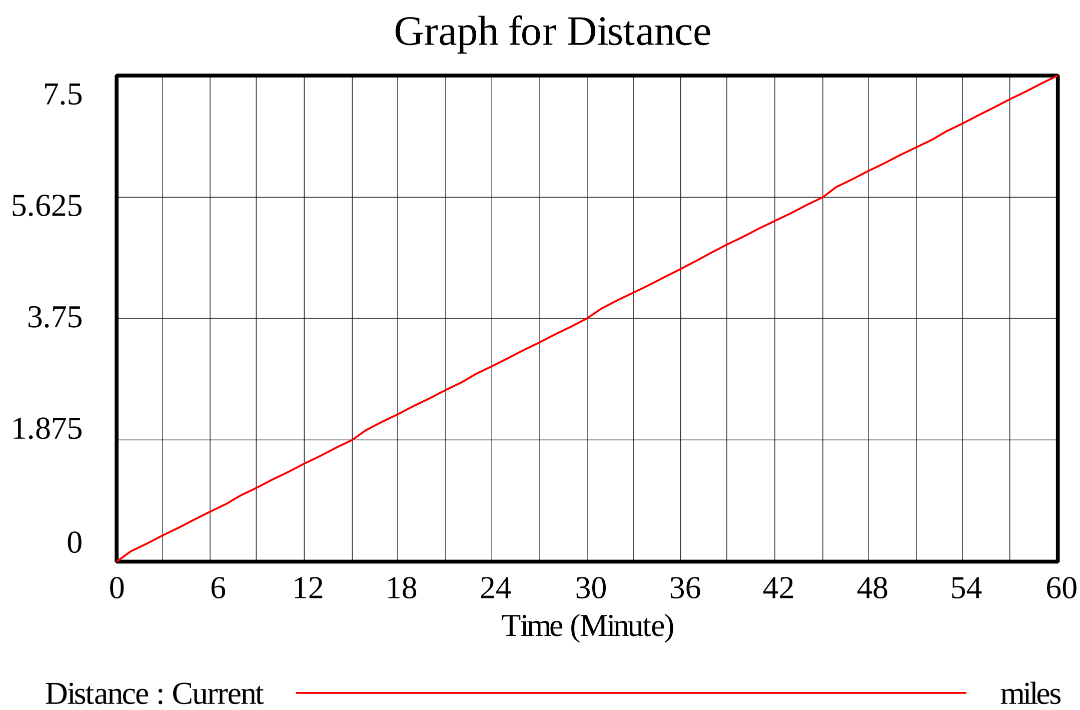


Figure 18: Vensim Equivalent of Simulation for Distance

Section 4.10: Velocity

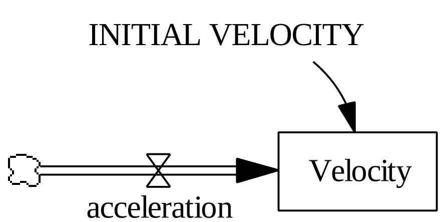


Figure 19: Vensim Equivalent of Velocity Model

Documentation for Velocity Model:

(1) acceleration = 5

Units: miles/hour/Second

The car accelerates at 5 miles per hour/second.

(2) FINAL TIME = 16

Units: Second

The final time for the simulation.

(3) INITIAL TIME = 0

Units: Second

The initial time for the simulation.

(4) INITIAL VELOCITY = 0

Units: miles/hour

(5) SAVEPER = TIME STEP

Units: Second

The frequency with which output is stored.

(6) TIME STEP = 0.0625

Units: Second

The time step for the simulation.

(7) Velocity = INTEG (acceleration, INITIAL VELOCITY)

Units: miles/hour

At the red light the car is stopped, so its velocity is 0.

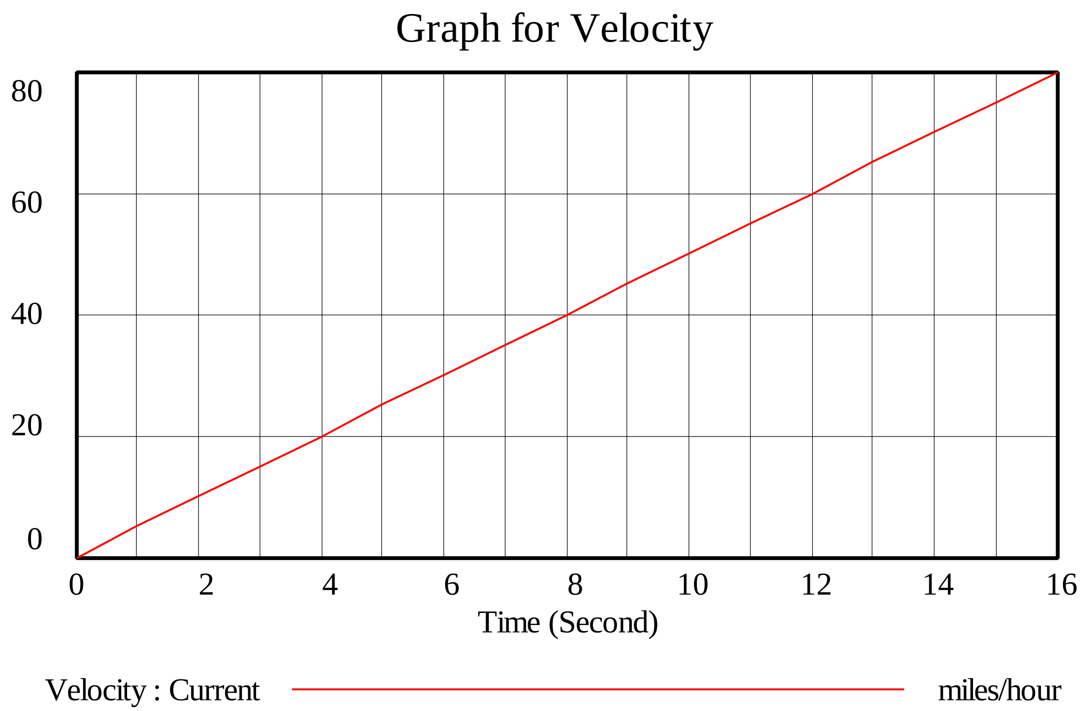


Figure 20: Vensim Equivalent of Simulation for Velocity

Section 4.11: Pinocchio's Nose

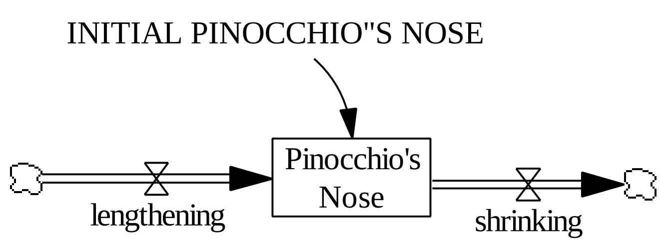


Figure 21: Vensim Equivalent of Pinocchio's Nose Model

Documentation for Pinocchio's Nose Model:

(1) FINAL TIME = 6

Units: Day

The final time for the simulation.

(2) INITIAL PINOCCHIO’S NOSE = 4

Units: centimeters

(3) INITIAL TIME = 0

Units: Day

The initial time for the simulation.

(4) lengthening = 8

Units: centimeters/Day

Pinocchio tells 8 lies each day and his nose lengthens 1 centimeter for each lie.

(5) Pinocchio's Nose = INTEG (lengthening-shrinking, INITIAL PINOCCHIO’S NOSE)

Units: centimeters

On Monday morning Pinocchio's nose is 4 centimeters long.

(6) SAVEPER = TIME STEP

Units: Day

The frequency with which output is stored.

(7) shrinking = 5

Units: centimeters/Day

Pinocchio performs 1 good deed each day and his nose shrinks 5 centimeters for that good deed.

(8) TIME STEP = 0.0625

Units: Day

The time step for the simulation.

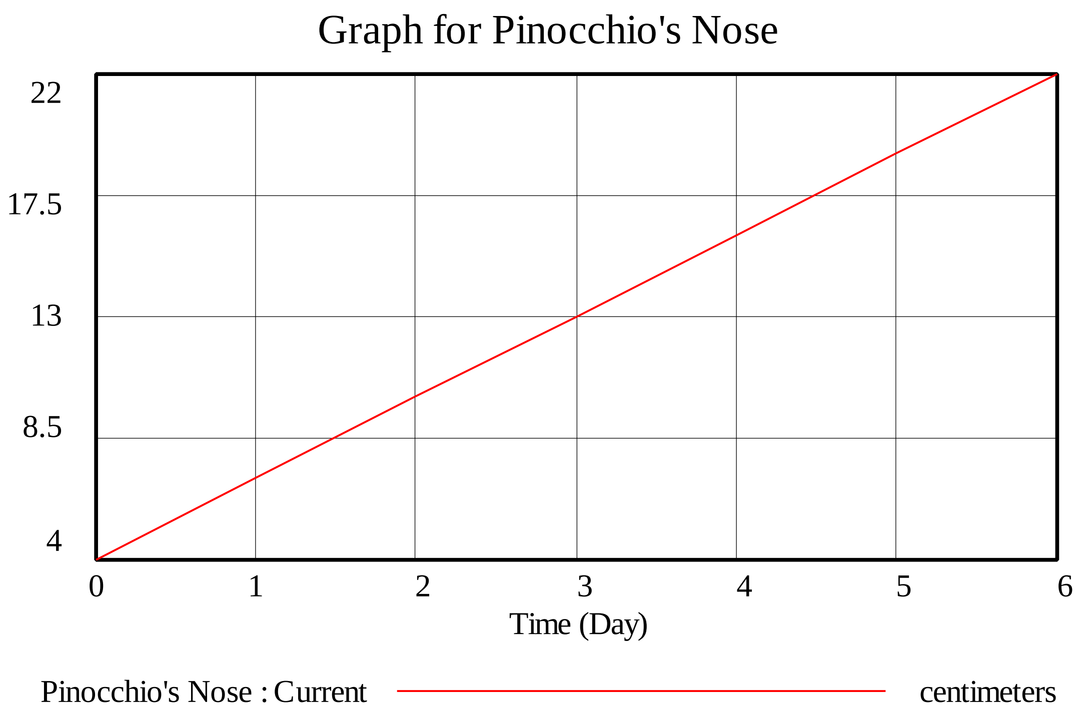


Figure 22: Vensim Equivalent of Simulation for Length of Pinocchio’s Nose

Section 4.12: Cavities

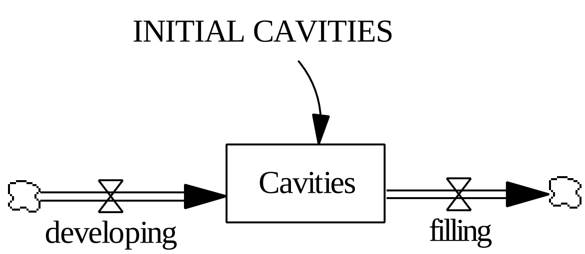


Figure 23: Vensim Equivalent of Cavities Model

Documentation for Cavities Model:

(1) Cavities = INTEG (developing-filling, INITIAL CAVITIES)

Units: cavities

I currently don't have any cavities.

(2) developing = 0.5

Units: cavities/Year

I develop a full-blown cavity every two years.

(3) filling = 0.333333

Units: cavities/Year

I get a cavity filled every three years.

(4) FINAL TIME = 15

Units: Year

The final time for the simulation.

(5) INITIAL CAVITIES = 0

Units: cavities

(6) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(7) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

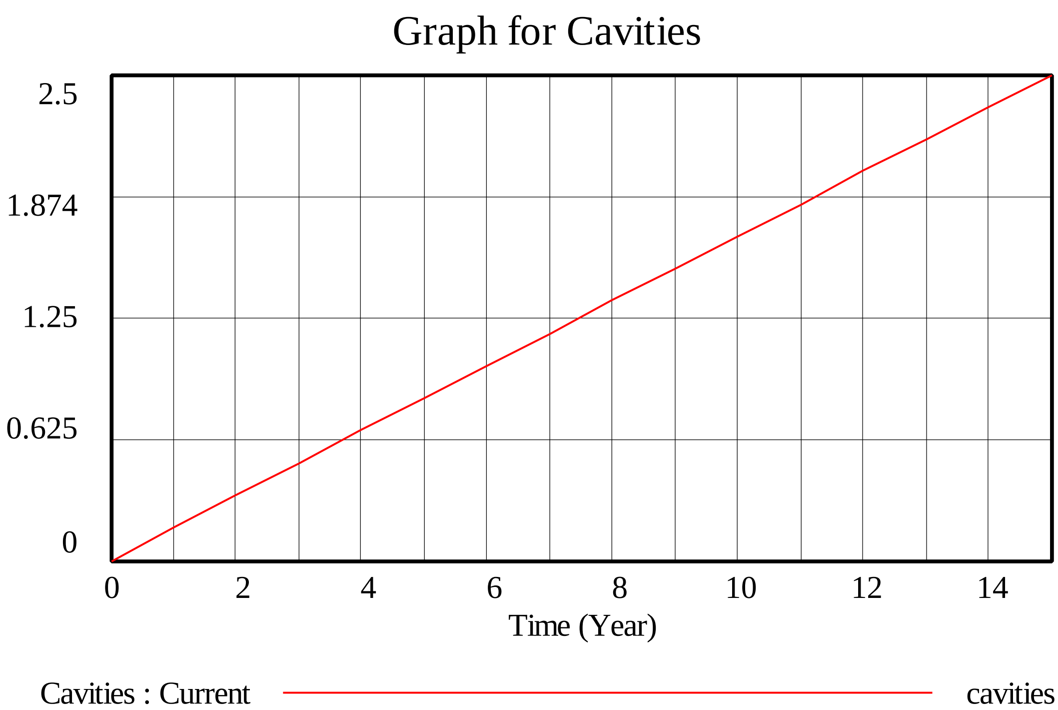


Figure 24: Vensim Equivalent of Simulation for Number of Cavities

Section 4.13: Money in Bank Account

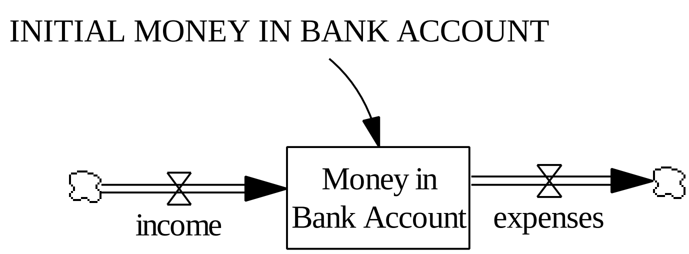


Figure 25: Vensim Equivalent of Money in Bank Account Model

Documentation for Money in Bank Account Model:

(1) expenses = 7.75 +60/3

Units: dollars/Week

She spends $.75 every week on a movie and $60 every three weeks on clothes.

(2) FINAL TIME = 16

Units: Week

The final time for the simulation.

(3) income = 120-23.7

Units: dollars/Week

Every week she gets a paycheck for $120 minus $23.70 in taxes.

(4) INITIAL MONEY IN BANK ACCOUNT = 678.53

Units: dollars

(5) INITIAL TIME = 0

Units: Week

The initial time for the simulation.

(6) Money in Bank Account = INTEG (+income-expenses, INITIAL MONEY IN BANK ACCOUNT)

Units: dollars

Stephanie has $678.53 in her bank account.

(7) SAVEPER = TIME STEP

Units: Week

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Week

The time step for the simulation.

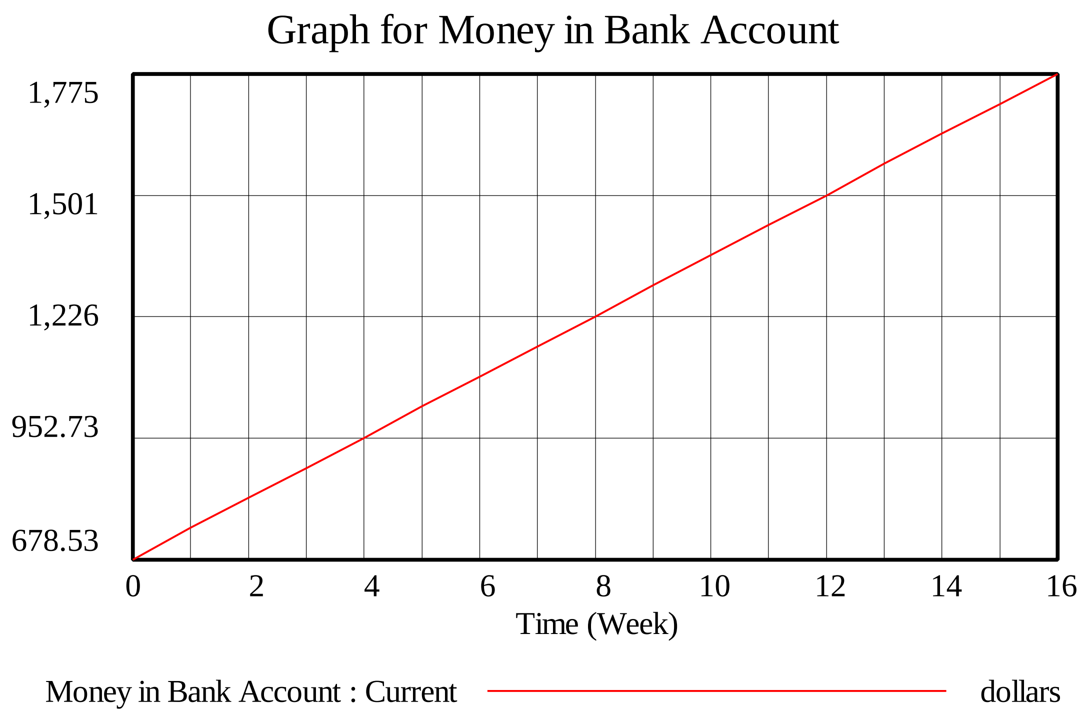


Figure 26: Vensim Equivalent of Simulation for Amount of Money in Bank Account

Section 4.14: Nuclear Weapons

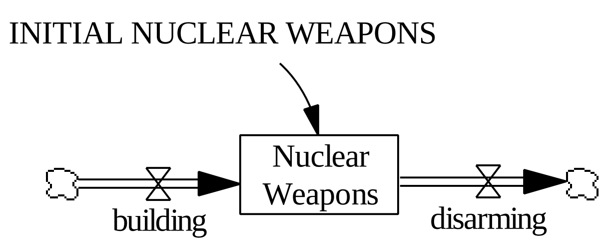


Figure 27: Vensim Equivalent of Nuclear Weapons Model

Documentation for Nuclear Weapons Model:

(1) building = 500

Units: weapons/Year

Every year Euroamerica builds 500 new nuclear weapons.

(2) disarming = 600

Units: weapons/Year

Every year Euroamerica disarms 600 nuclear weapons.

(3) FINAL TIME = 2010

Units: Year

The final time for the simulation.

(4) INITIAL NUCLEAR WEAPONS = 10000

Units: weapons

(5) INITIAL TIME = 1990

Units: Year

The initial time for the simulation.

(6) Nuclear Weapons = INTEG (building-disarming, INITIAL NUCLEAR WEAPONS)

Units: weapons

In 1990 Euroamerica has 10,000 nuclear weapons.

(7) SAVEPER = TIME STEP

Units: Year

The frequency with which output is stored.

(8) TIME STEP = 0.0625

Units: Year

The time step for the simulation.

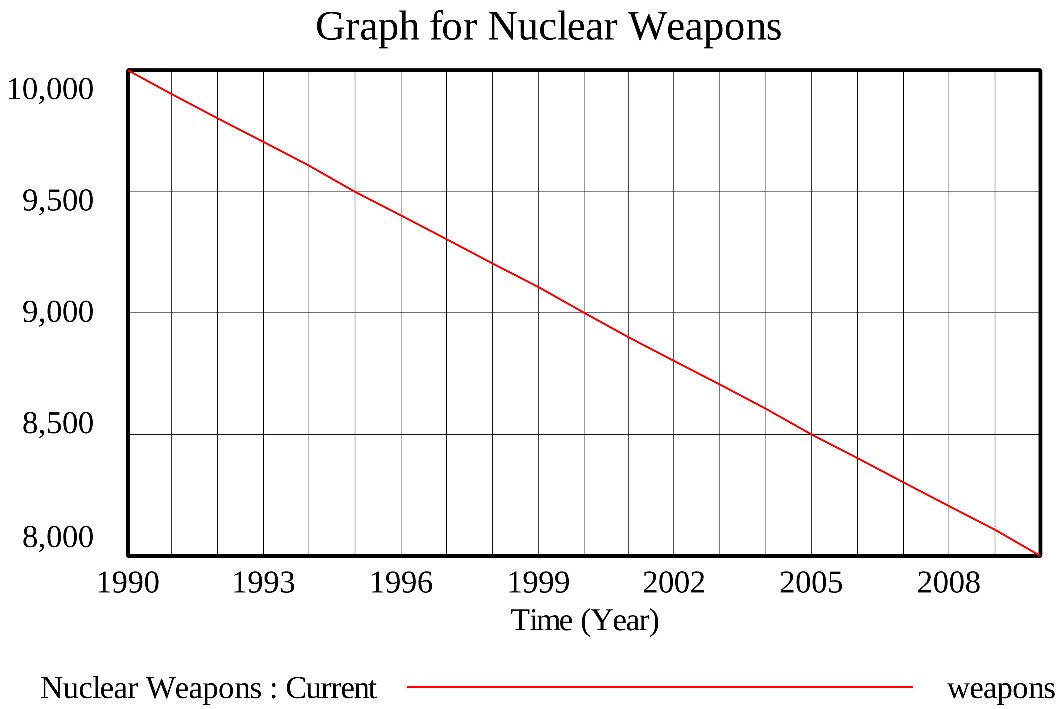


Figure 28: Vensim Equivalents of Simulation for Number of Nuclear Weapons