Appendix

The correct answers to the questions are given in red.
They were, for obvious reasons,not included with the questionnaires administered to the participants.

A1: The easy bathtub task

A2: The inverted easy bathtub task

A3: Exponential growth

A4: Compensate for rabbits killed

A5: Mathematically balancing rabbits

A6: Mathematically balancing foxes

A7: Hugo's bath flows

A8: Hugo's bath stock

A9: Fox control - transport

A10: Fox control - balance

A11: Fox control -hunting

A12: Hotel – line graph

A13: Hotel - table

A14: Rabbit-fox growth

A15: Rabbit-fox decline

A16: Rabbit-fox equilibrium

A17: Rabbit-fox "bump"

A18: The difficult bathtub task

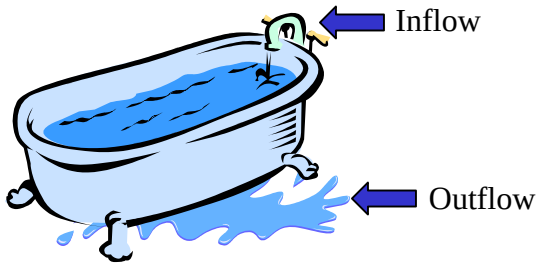
A19: Distance from speed

A20: Velocity (a) and distance (b) from acceleration

A1

Administered to Group X

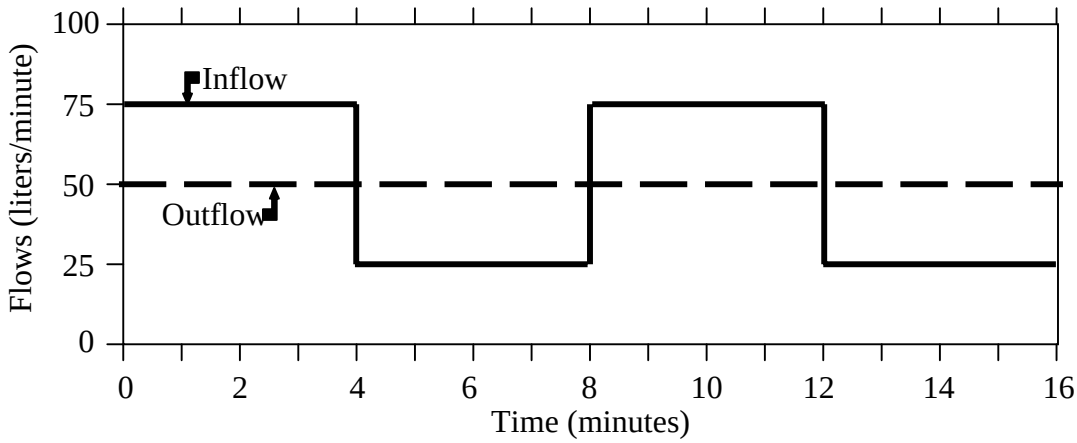
Consider the bathtub shown below. Water flows in at a certain rate, and exits through the drain at another rate.

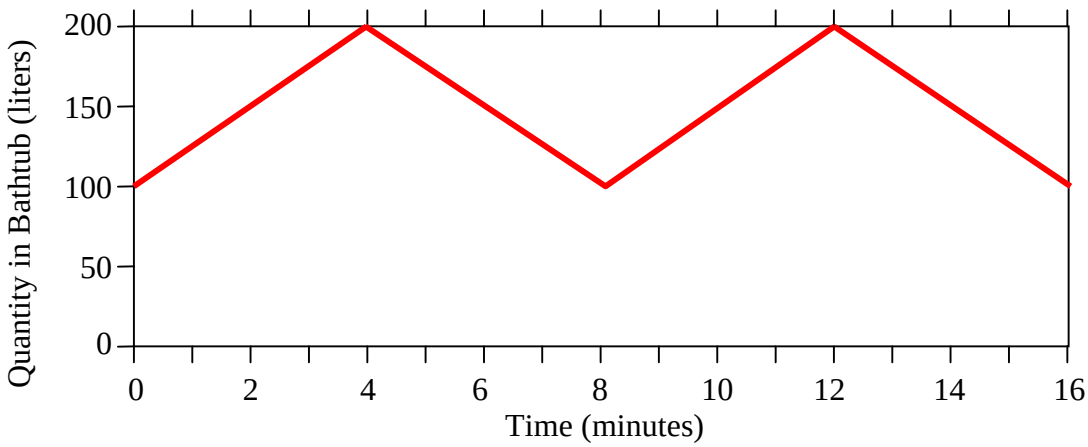


Reproduced from "Bathtub dynamics: initial results of a systems dynamics inventory" by L. Booth Sweeney and J. D. Sterman, 2000, *System Dynamics Review, 16(4),* p. 253

The graph below shows the hypothetical behavior of the inflow and outflow rates for the bathtub. From the information, draw the behavior of the quantity of water in the tub on the second graph below.

Assume the initial quantity in the tub (at time zero) is 100 liters.

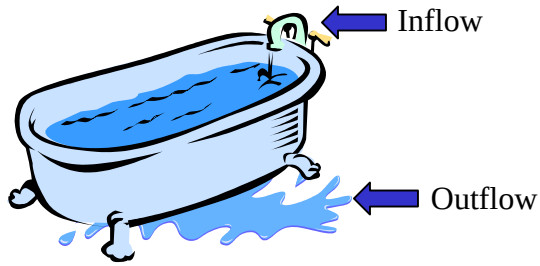




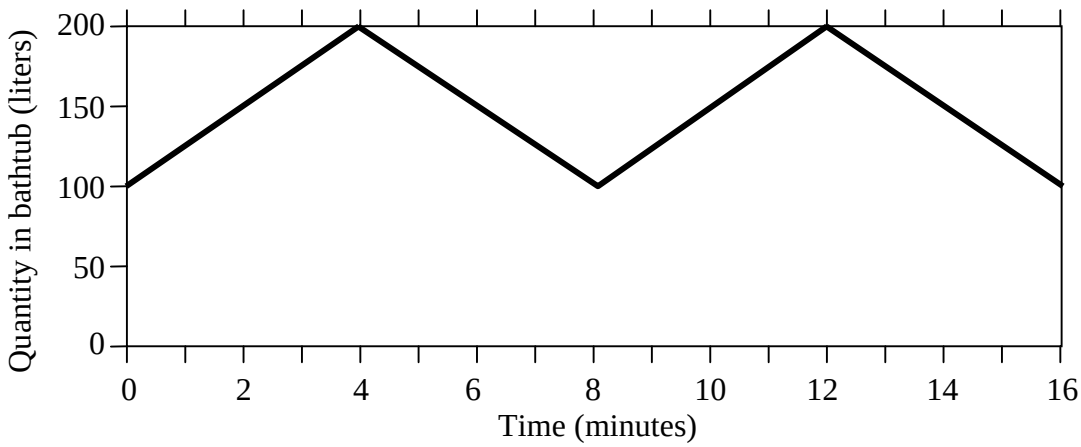
A2

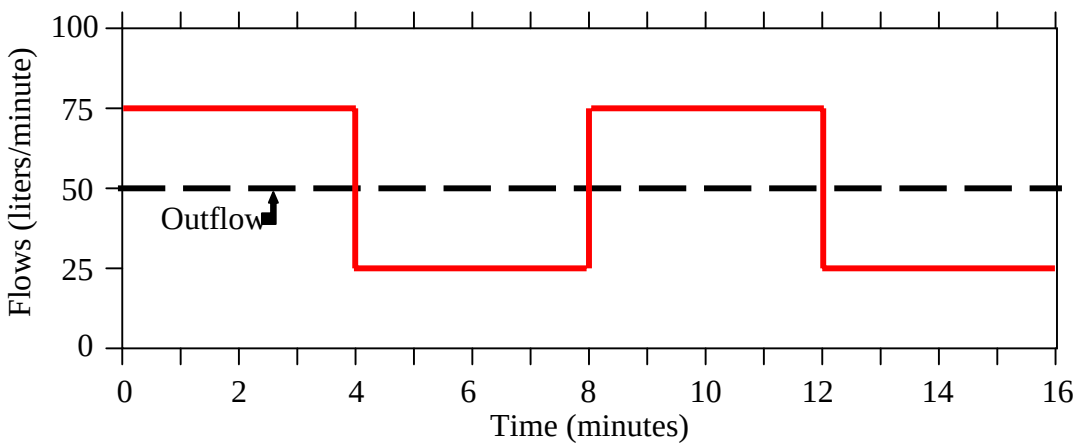
Administered to Group Y

Consider the bathtub shown below. Water flows in at a certain rate, and exits through the drain at another rate.



The graph below shows the hypothetical behavior of the quantity of water in the bathtub. From the information, draw the behavior of the inflow rate for tub the on the second graph below. The outflow rate is 50 liters/minute.





A3

Administered to both groups

Imagine a fast growing species of pond lilies, that doubles every day.

a) If it takes 30 days to completely cover a pond, when will the pond will ¼ covered?

Two days earlier.

b) When will it be ½ covered?

The day before.

A4

Administered to both groups

If foxes are the only threat to a population of rabbits, the foxes collectively kill and eat 600 rabbits each year, and there are 4 rabbits born per every adult rabbit and year, how many adult rabbits are required for the rabbits population not to be reduced? (Assume the rabbits reach adulthood by the age of one year.)

At least 150 rabbits are required.

A5

Administered to Group X

If the situation for the rabbits and foxes (in 3a) is instead that:

> every rabbit produces 5 offspring a year,
>
> for every 200 rabbits eaten a fox is born,
>
> every fox consumes 1 % of the rabbits a year,
>
> 10 % of the foxes die each year.

Give an algebraic expression for (existing foxes = F and existing rabbits = R)

a) the number of rabbits born a year

5R

b) the number of rabbits eaten a year

0.01RF

c) In equilibrium, when both the rabbit and the fox population are constant, how many rabbits are born in relative to how many that are killed?

Equal numbers are born that die.

d) Can you use anything of what you have arrived at in a-c above to conclude anything about the rabbits and/or foxes in equilibrium, and, if so, what and how?

Yes. $5R = 0.01RF \Rightarrow F = 500$; In equilibrium, the number of foxes is 500.

A6

Administered to Group Y

If the situation for the rabbits and foxes (in 3a) is instead that:

> every rabbit produces 5 offspring a year,
>
> for every 200 rabbits eaten a fox is born,
>
> every fox consumes 1 % of the rabbits a year,
>
> 10 % of the foxes die each year.

Give an algebraic expression for (existing foxes = F and existing rabbits = R)

a) the number of foxes born a year

0.01RF/200

b) the number of foxes dead a year

0.1F

c) In equilibrium, when both the rabbit and the fox population are constant, how many foxes are born in relative to how many that die?

Equal numbers are born that die.

d) Can you use anything of what you have arrived at in a-c above to conclude anything about the rabbits and/or foxes in equilibrium, and, if so, what and how?

Yes. $0.01RF/200 = 0.1F \Rightarrow R = 2000$;

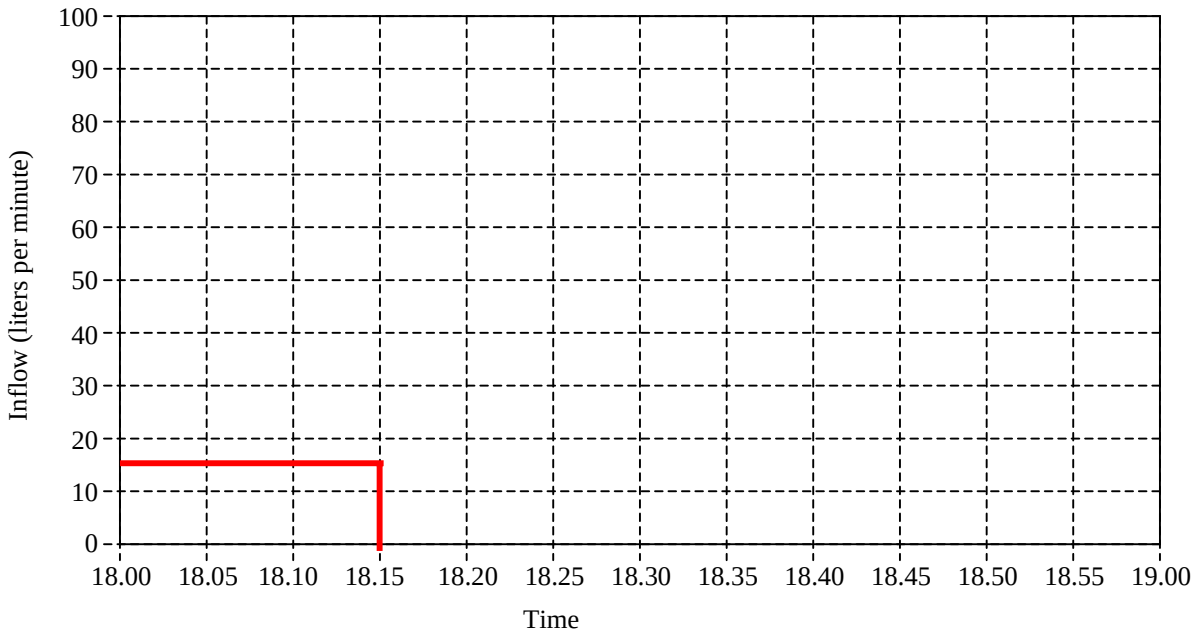
In equilibrium, the number of rabbits is 2000.

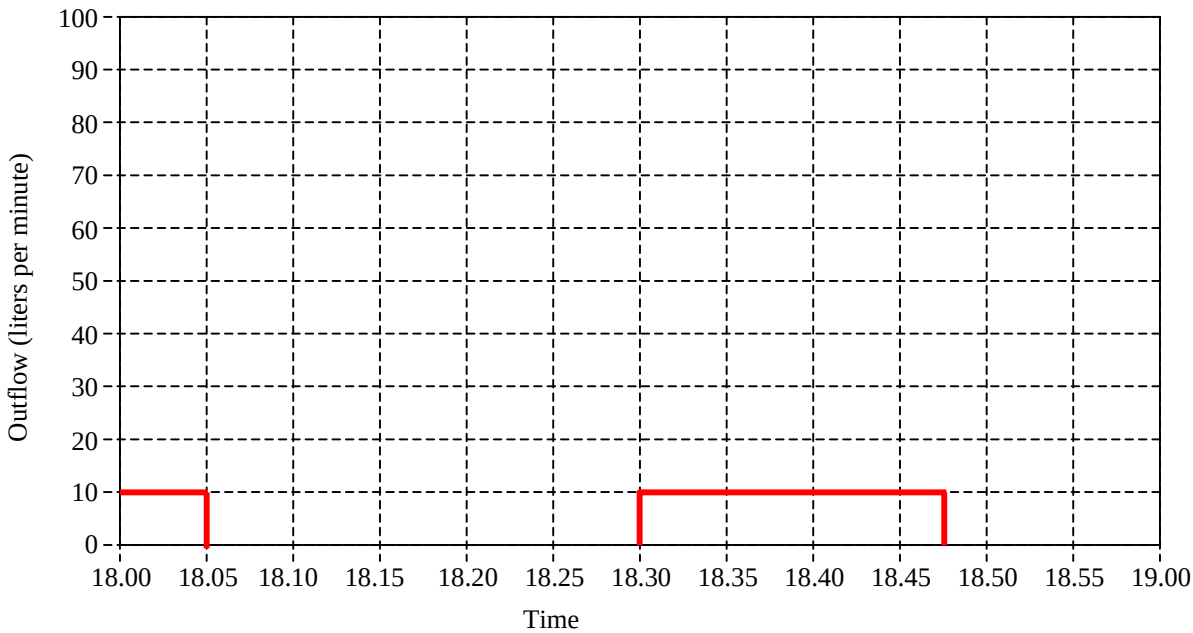
A7

Administered to Group X

Hugo wants to have a bath before he goes out on Saturday evening. He turns on the faucet at 18.00 sharp. The water flows in at a constant rate of 15 liters per minute. Hugo, however, forget o close the outlet, so water is flowing out at a rate of 10 liters per minute. At 18.05 Hugo enters the bathroom and closes the outlet. At 18.15 Hugo closes the faucet and enjoys his bath during 15 minutes. Than he opens the drain to empty the bathtub.

Draw the behavior of the inflow (the upper graph) and outflow (the lower graph) of Hugo's bathtub between 18.00 and 19.00 this Saturday evening.



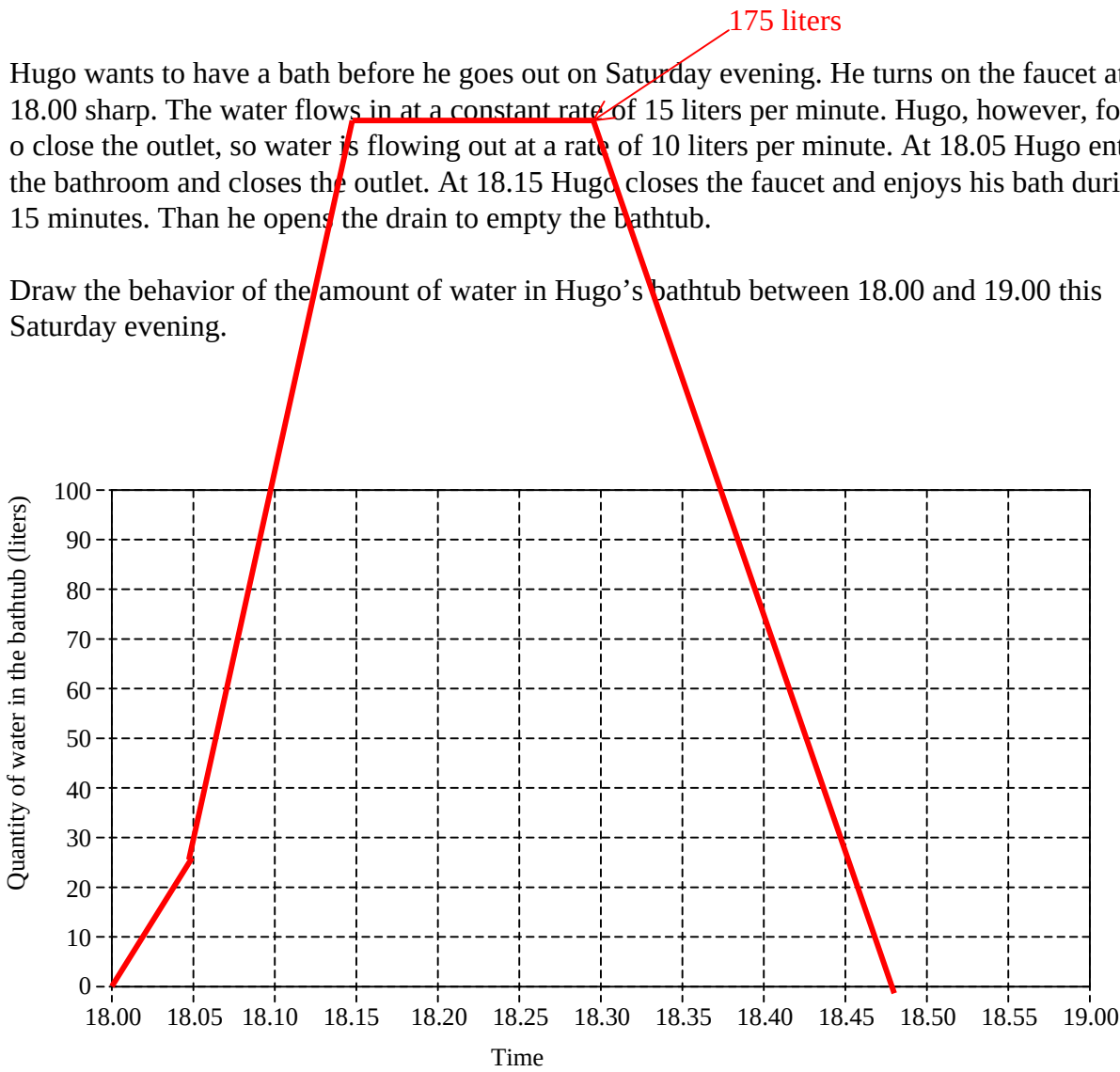


A8

Administered to Group Y

Hugo wants to have a bath before he goes out on Saturday evening. He turns on the faucet at 18.00 sharp. The water flows in at a constant rate of 15 liters per minute. Hugo, however, forget o close the outlet, so water is flowing out at a rate of 10 liters per minute. At 18.05 Hugo enters the bathroom and closes the outlet. At 18.15 Hugo closes the faucet and enjoys his bath during 15 minutes. Than he opens the drain to empty the bathtub.

Draw the behavior of the amount of water in Hugo's bathtub between 18.00 and 19.00 this Saturday evening.



Inspired by "Can students learn stock-flow thinking" by D. Kainz and G. Ossimitz. 2002. Proceedings of the 20th International Conference of the System Dynamics Conference. Palermo, Italy. The Maier's bathtub stock (Y4), and bathtub flow (X4) tasks.

A9

Administered to both groups

Imagine (once again) an island on which the only animal life consists of rabbits and foxes. You are the assigned fox keeper. Your task is too keep the fox population at a size adequate to keep the rabbit population within desired limits, which is somewhere between 500 and 1500 rabbits.

You may have foxes transported to and from the island at your request.

The conditions for the rabbits and foxes are:

> Every rabbit produces 2 offspring a year.
>
> For every 180 rabbits eaten a fox is born,
>
> Every fox consumes 4 % of the rabbits a year.
>
> 20 % of the foxes die each year.

During the last two years, no foxes have been transported. The development during that time:

	Two years ago	One year ago	Now
Foxes	40	41	46
Rabbits	1000	1400	1780

What decision do you want to make regarding the size of the fox population?

How many foxes do you wish to have on the island?

Any request for a larger fox population, within reasonable limits, that is not exceeding 100, would be accepted as a correct answer.

A10

Administered to Group X

(Same as in A9)

> Every rabbit produces 2 offspring a year.
>
> For every 180 rabbits eaten a fox is born,
>
> Every fox consumes 4 % of the rabbits a year.
>
> 20 % of the foxes die each year.

New directions: Due to economical restraints, one wishes to eliminate the need for fox transports. The goal is to achieve a stable balance, an equilibrium, between the rabbits and the foxes, so the foxes remains at a constant level without any transports, and that the rabbits at the same time are kept at a constant level by these foxes.

In consideration of this task, start by focusing on the foxes:

a) If more foxes are born than die, why is that so?

It could be either that there are a lot of foxes eating rabbits and producing offspring. It could also be that there are a lot of rabbits, the foxes eat a lot of rabbits each and produce a lot of offspring. It could also be a combination of those two.

b) What could be done so that less foxes are born? Can this be obtained in more than one way? Which one(s)?

1. Reduce the fox population.

2. Increase the fox population to reduce the rabbit population. Then reduce the fox population to an appropriate level.

c) Which way would be the preferable one, considering the goal to achieve an equilibrium situation for the foxes and the rabbits?

Alternative 2. If the fox population is reduced when the rabbit population is large enough to sustain a large fox population, the rabbit population will increase dramatically. The preferred solution for approaching an equilibrium situation is therefore alternative 2: reduce the rabbit population.

A11

Administered to Group Y

(Same as in A9)

> Every rabbit produces 2 offspring a year.
>
> For every 180 rabbits eaten a fox is born,
>
> Every fox consumes 4 % of the rabbits a year.
>
> 20 % of the foxes die each year.

New directions: For economic reasons, fox transports will no longer be permitted. The size of the fox population will from now on be regulated by hunting. Hunting is the only means at your disposal for regulating the number of foxes.

During the last two years, no foxes have been shot (or transported).
The development during that time:

	Two years ago	One year ago	Now
Foxes	60	61	57
Rabbits	1000	580	347

a) What decision do you wish to make concerning the foxes now? How many foxes do you wish to have on the island?

Any request for a reduced fox population would be accepted as a correct answer.

b) Is there anything in particular that you need to consider with these new prerequisites? (If so, what?)

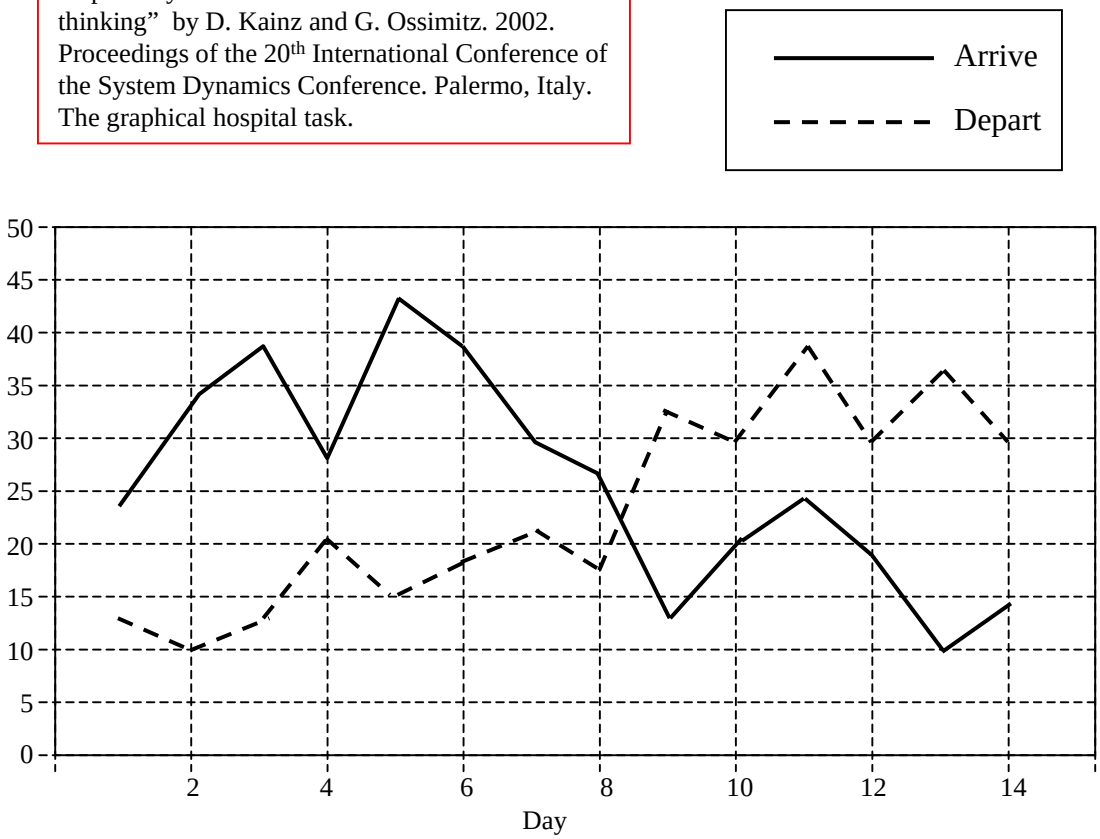
Since importing foxes are no longer allowed, I need to be careful not to reduce the fox population too much. It will take some years to rebuild the fox population, and during that time the rabbit population might grow way out of limits.

A12

Administered to Group X

The graph below describe how many guests that arrive and depart from a hotel each day during a two-week period.

Inspired by "Can students learn stock-flow thinking" by D. Kainz and G. Ossimitz. 2002. Proceedings of the 20th International Conference of the System Dynamics Conference. Palermo, Italy. The graphical hospital task.



a) What day during this period is there the largest number of guest staying at the hotel?

Day 8

b) On what day do the largest number of guests arrive at the hotel?

Day 5

c) On what day do the largest number of guests depart from the hotel?

Day 11

A13

Administered to Group Y

The table below describe how many guests that arrive and depart from a hotel each day during a two-week period.

Day	Arrive	Depart	Day	Arrive	Depart
1	24	13	8	27	18
2	33	10	9	13	33
3	38	13	10	20	30
4	28	20	11	24	38
5	43	15	12	19	30
6	38	18	13	10	41
7	30	21	14	14	30

a) What day during this period is there the largest number of guest staying at the hotel?

Day 8

b) On what day do the largest number of guests arrive at the hotel?

Day 5

c) On what day do the largest number of guests depart from the hotel?

Day 13

Inspired by "Can students learn stock-flow thinking" by D. Kainz and G. Ossimitz. 2002. Proceedings of the 20th International Conference of the System Dynamics Conference. Palermo, Italy. The tabular hospital task.

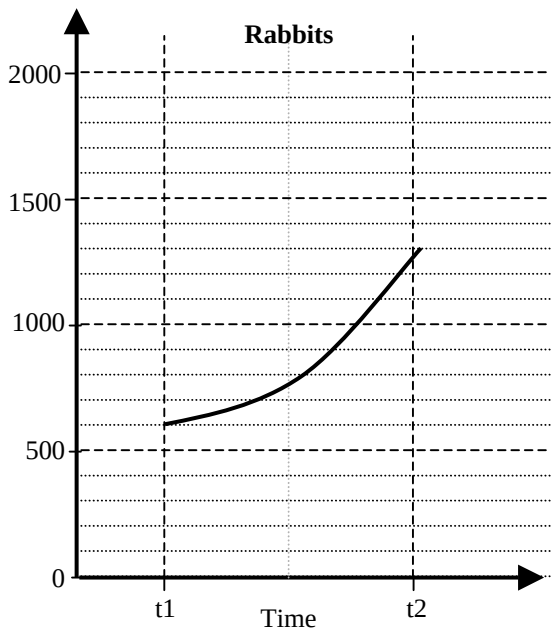
A14

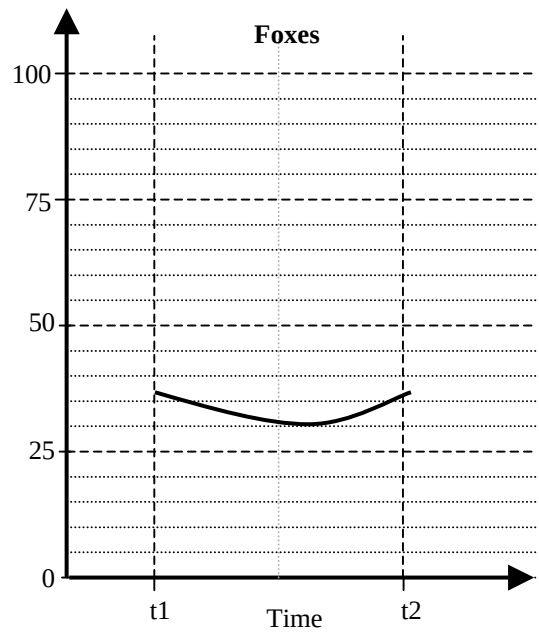
Administered to Group X

Again, imagine an island with an animal life of only rabbits and foxes. Of these, the following is known:

> The rabbits produce offspring.
> The foxes eat rabbits (the major cause of death for the rabbits).
> The foxes do also produce offspring.
> And, a number of foxes die each year.

Study the the graphs below and describe what happen to the rabbits and the foxes between time t1 and t2. Do also explain why the situation has evolved this way for the rabbits and the foxes.





What happens to the rabbits? Why?	What happens to the foxes? Why?
The rabbit population grows from 600 to 1300 at and an increasing rate. The foxes are not many enough to keep the rabbit population down.	The fox population remains fairly constant near 35. First, it decreases a little, down to 30, in lack of enough food, due to a small rabbit population. When the rabbit population grows larger, the fox population recovers, and will continue to grow beyond t2.

A15

Administered to Group Y

Again, imagine an island with an animal life of only rabbits and foxes. Of these, the following is known:

> The rabbits produce offspring.
> The foxes eat rabbits (the major cause of death for the rabbits).
> The foxes do also produce offspring.
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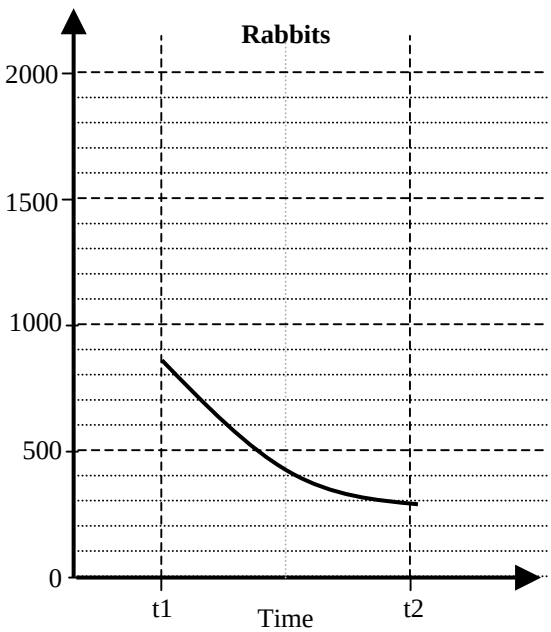
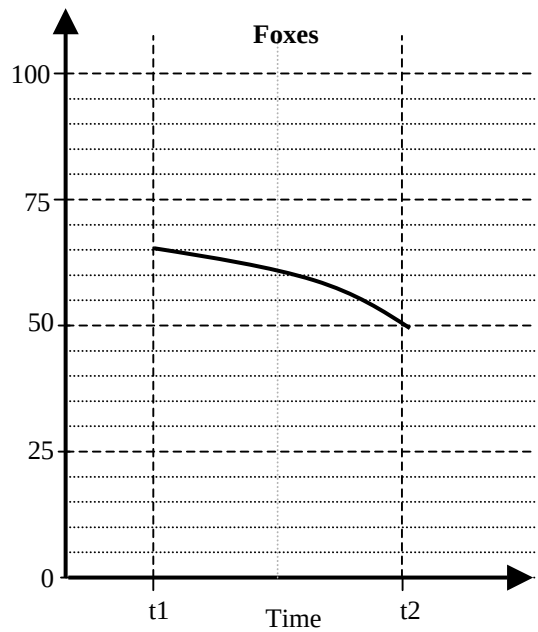
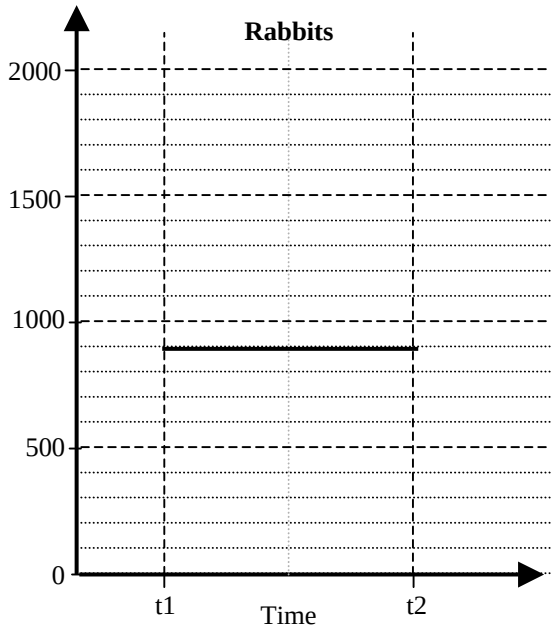


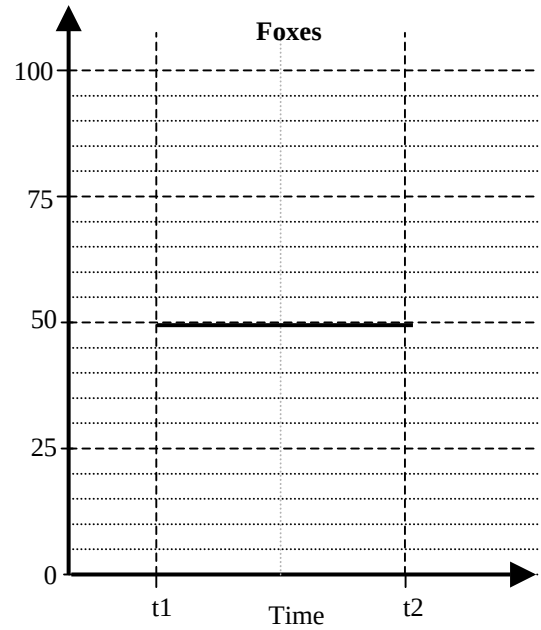


What happens to the rabbits? Why?	What happens to the foxes? Why?
The rabbit population decline at and a decreasing rate from around 850 to 300. There are a lot of foxes, and they reduce the rabbit population substantially. Eventually, the fox population is also reduced to a level low enough for the decline in rabbit population to level off.	The fox population declines from 65 to 50 at a slightly increasing rate. The fox population decreases at an increasing rate due to an increasingly diminishing supply of food.

A16

Administered to Group X

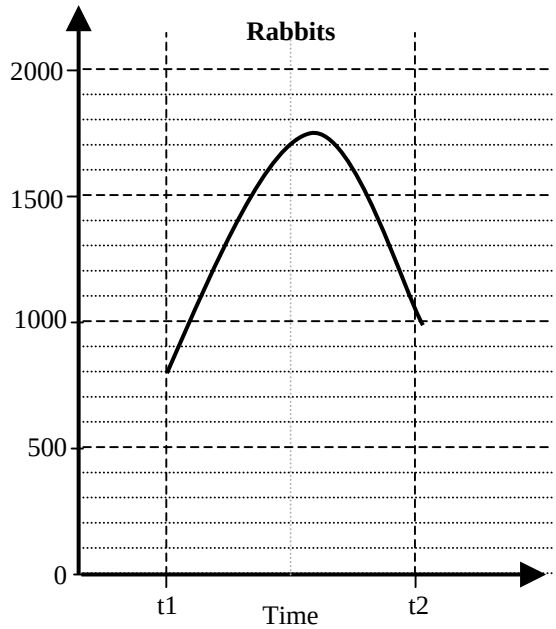


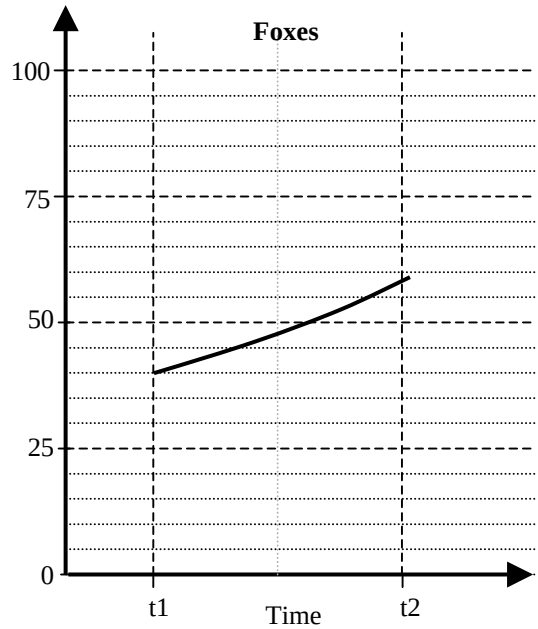


What happens to the rabbits? Why?	What happens to the foxes? Why?
The rabbit population remains constant at 900 rabbits. An equilibrium has been reached between rabbits and foxes. Equally many rabbits are born that are killed by foxes.	The fox population remains constant at 50 foxes. An equilibrium has been reached between rabbits and foxes. Equally many foxes are born that die.

A17

Administered to Group Y



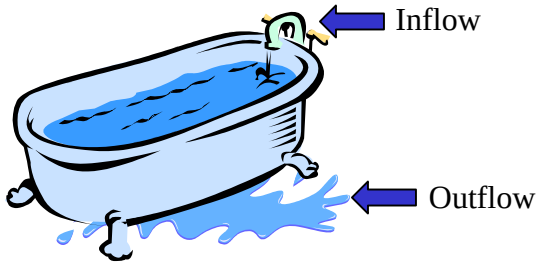


What happens to the rabbits? Why?	What happens to the foxes? Why?
The rabbit population grows from 800 for a little more than half the period to around 1750, and then decline for the rest of the period down to 1000. Initially, there are too few foxes to keep the rabbit population down. However conditions are excellent for the foxes. They reproduce rapidly and by mid-period (or slightly after) they are numerous enough to bring about a decline in the rabbit population.	The fox population grows from 40 to approximately 58. The foxes have food enough to maintain a high reproduction rate throughout the entire period.

A18

Administered to both groups

Consider the bathtub shown below. Water flows in at a certain rate, and exits through the drain at another rate.



Reproduced from "Bathtub dynamics: initial results of a systems dynamics inventory" by L. Booth Sweeney and J. D. Sterman, 2000, *System Dynamics Review, 16(4)*, pp. 253-254

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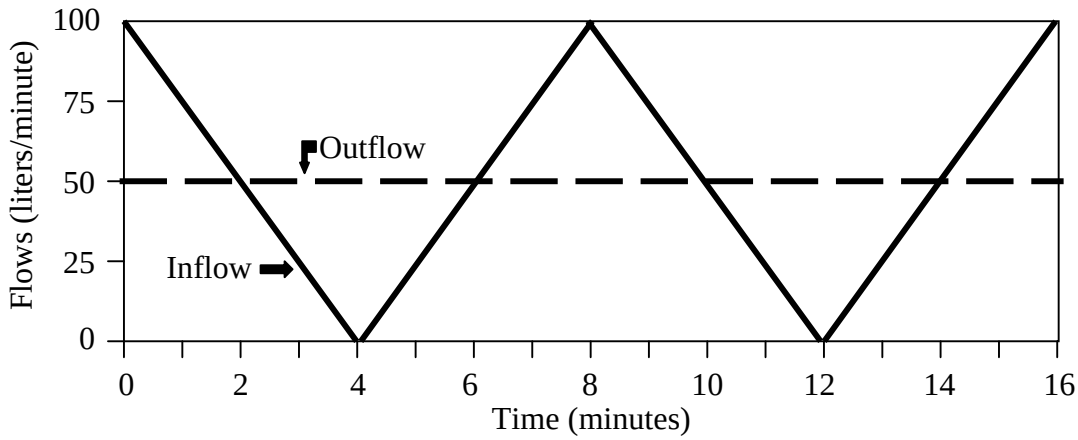
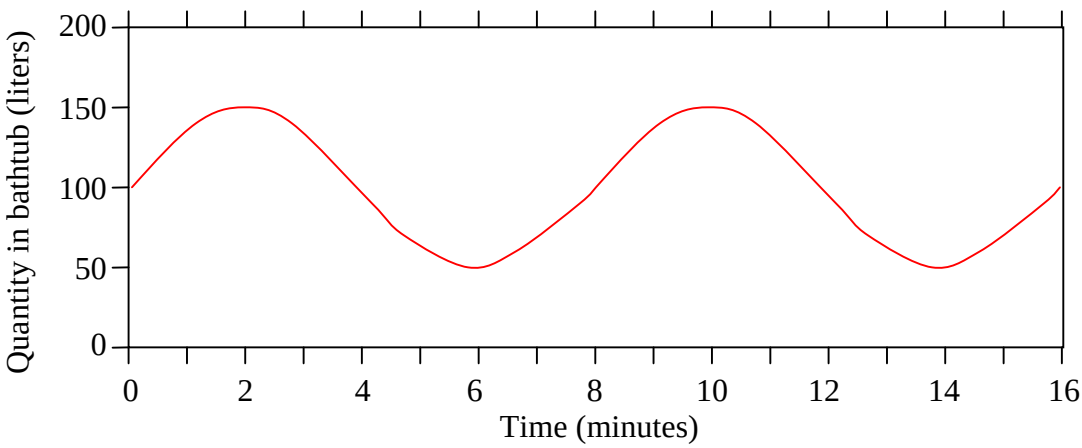
Assume the initial quantity in the tub (at time zero) is 100 liters.





A19

Administered to both groups

If a car travels at a speed of 70 kilometers/hour for 1½ hour, and then at 85 kilometers/hour for 2 hours, how far has the car traveled?

275 km

A20

Administered to both groups

If a vehicle accelerate from standstill at 2 m/s^2 (minutes/$second^{2)}$ for one minute,

a) what velocity will the vehicle have reached? 120 m/s

b) b) how far will it have traveled during this minute? 3600 m, or 3.6 km