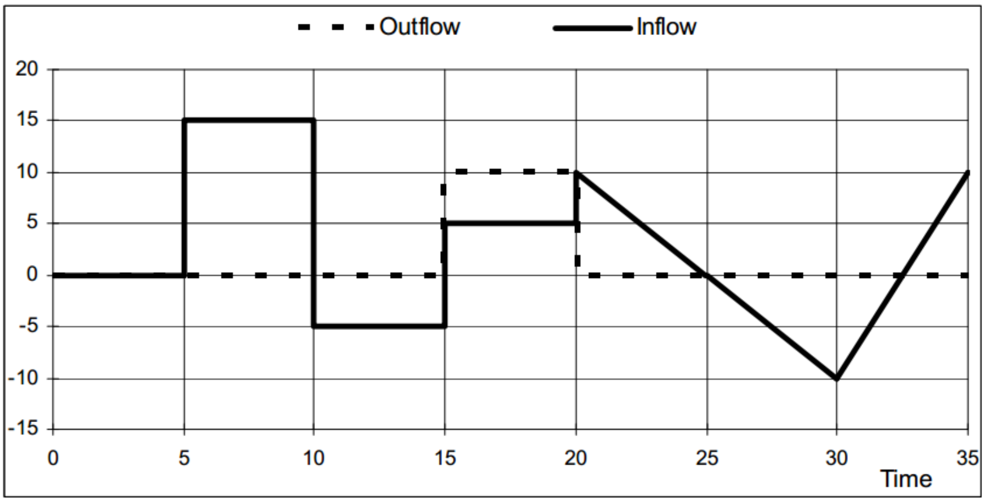
ASSIGNMENT 2

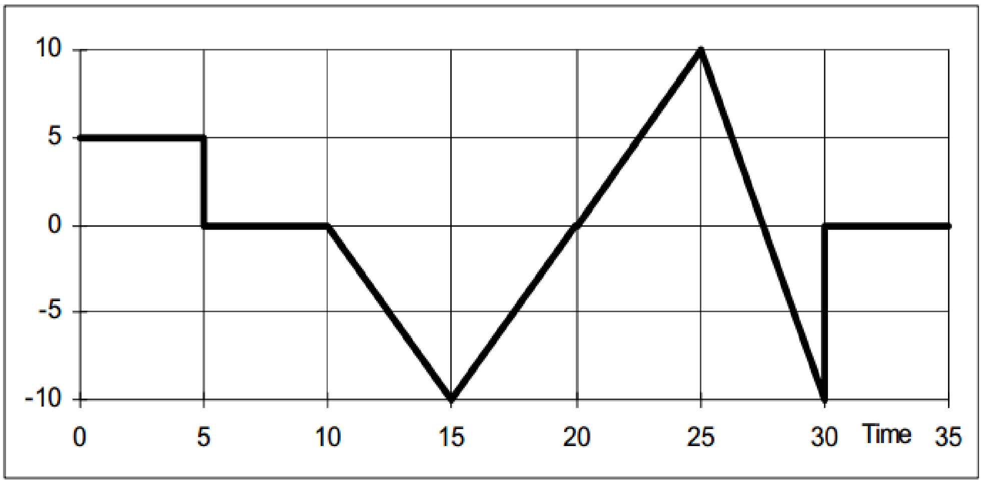
2.1.

Graphical integration. In the figure below, you see inflow and outflow, or net flow. Produce a diagram showing how the stock develops (remember the three questions to ask: direction, size, and shape). Assume that the stock is zero to begin with (time=0). Make sure that you number the axis and that you are accurate.

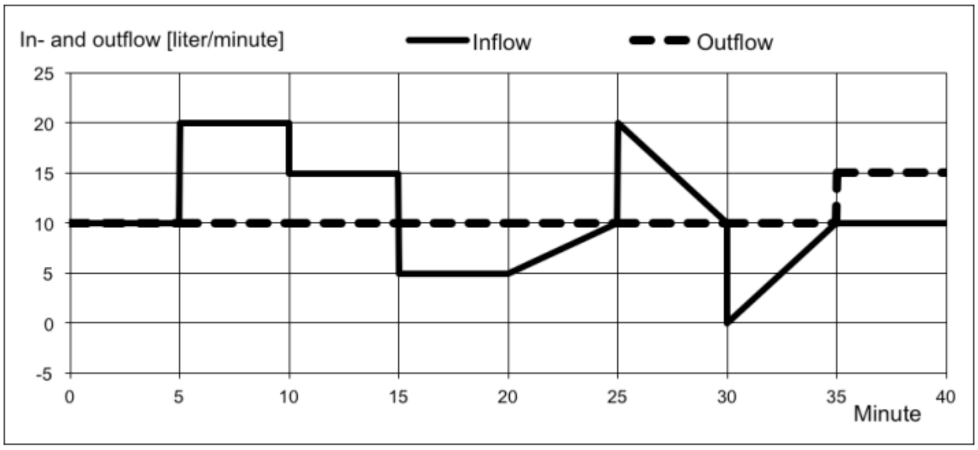
a) Inflow and Outflow



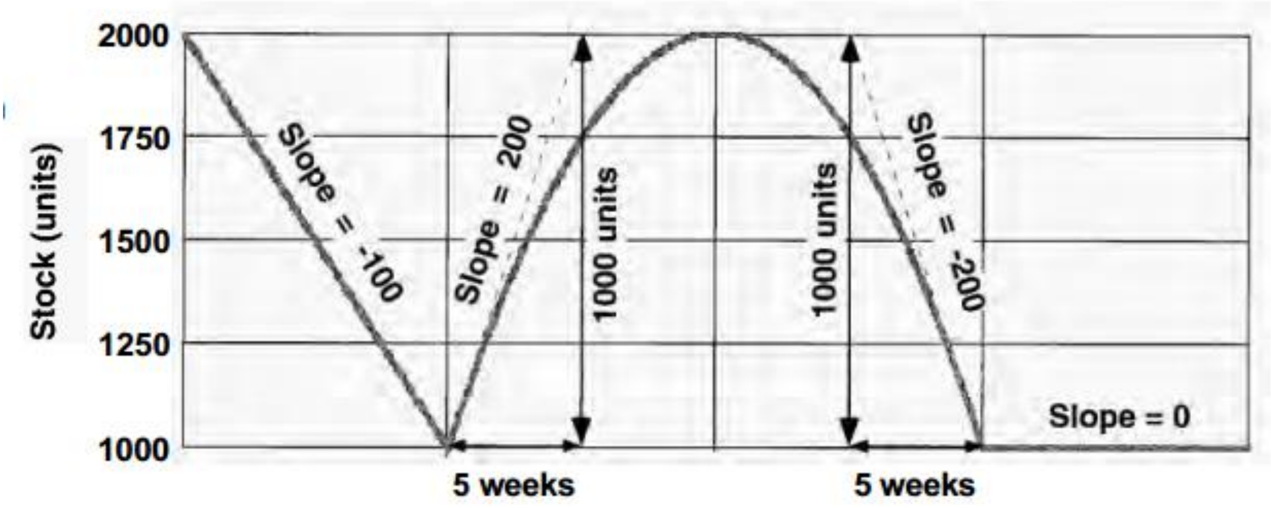
b) Net Flow



c) Inflow and Outflow



d) Graphical differentiation. In the figure below, you see behavior of stock. Produce a diagram showing how the net flow develops.



2.2.

Many high school students in physics classes have difficulties understanding the relationships between acceleration, speed and distance. Some of you may remember a formula for distance saying that:

*Distance=1/2*Acceleration*Time.*

See if you can explain this formula by using stock and flow diagrams plus graphical integration (Do NOT use Stella at this stage!). Follow the steps below.

a) First consider acceleration and speed. The word "accelerate" means “to increase speed”. Draw a stock and flow diagram. Assume that the speed is zero at time zero. Acceleration is constant and equal to 10 meters/second^2 (approximately the acceleration of an object that falls towards the earth with no air resistance). Use graphical integration (ask the 3 questions) and draw a graph showing the development of speed over a 4-second period.

b) Next consider speed and distance. Note that speed is a measure of how long distance an object travels over a given period of time. Draw a stock and flow diagram. Assume that the distance travelled is zero at time zero. Assume that the speed develops as you found in point a). Use graphical integration and draw a graph showing the development of distance over the same 4-second period.

c) Compare the result of your graphical integration with the above formula. Do you get the same numbers for distance after four seconds with both methods? Can you explain why distance depends on time squared and can you explain the term ½ in the formula ?

2.3.

Using Stella to simulate.

a) Build in Stella the model of speed and distance from question 2.2. Print your Stella SFD and equations for the model. Make sure that all variables have correct units. Note that in Stella you need two different names for Speed, you may use the terms Speed for the stock and ‘Change in distance’ for the flow that influences distance. (This is one quite rare case where a stock is also the exact flow for another stock).

b) Simulate the model with the same initial values and the same constant acceleration as in question 2.2.

- Create a time graph with scale from 0 (ZERO) to 80 for all three variables.
- Why is it usually preferable to use a scale starting at zero?
- Create an output table and choose report *Interval* equal to 1 (second).

- Choose Run Specs… from the Model menu and set unit of time to 'Other' and write seconds. Set Length of simulation from 0 to 4 (seconds). Choose Euler´s Method and DT=0.001 (second). In Stella the Timestep is denoted DT. Simulate and show acceleration, speed and distance in the time graph and in the output table. Compare to results from question 2.1 and consider the accuracy of the simulated time behavior.

ASSIGNMENT 3

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3.1.

2.3 *Build in Stella the model of speed and distance from question 2.2. Print your Stella SFD and equations for the model. Make sure that all variables have correct units. Note that in Stella you need two different names for Speed, you may use the terms Speed for the stock and 'Change in distance' for the flow that influences distance. (This is one quite rare case where a stock is also the exact flow for another stock).*

Simulate the model with the same initial values and the same constant acceleration as in question 2.2.

- Create a time graph with scale from 0 (ZERO) to 80 for all three variables.

- Why is it usually preferable to use a scale starting at zero?

- Create an output table and choose report Interval equal to 1 (second).

- Choose Run Specs… from the Model menu and set unit of time to 'Other' and write seconds. Set Length of simulation from 0 to 4 (seconds). Choose Euler´s Method and DT=0.001 (second). In Stella the Timestep is denoted DT. Simulate and show acceleration, speed and distance in the time graph and in the output table. Compare to results from question 2.1 and consider the accuracy of the simulated time behavior.

c) Set DT=1 second and simulate. Recall the equation for Euler integration:

Stock(t) = Stock(t-1) + Timestep*(Inflow(t-1) – Outflow(t-1))

Use this equation to explain why the simulation shows correct results for Speed and too low values for Distance.

d) Go to Model>Run Specs… and select integration method Runge-Kutta 4 (RK4) rather than Euler's method. Keep DT=1 (second). Comment on accuracy, you do not have to explain.

e) Keep the Runge-Kutta 4 method and let acceleration increase linearly from zero to 10 m/s^2 over the 4-second interval. Model acceleration as a linear and instantaneous function of the variable called *time (time* does not have to be modelled; it is a variable that exists in the Stella program itself). Simulate for different DTs and report results for the highest DT that does not lead to changes in the second decimal for distance after 4 seconds. You may change the scale on the vertical axis.

3.2.

a) Explain why it does not matter for the analysis whether you for instance measure all flows in "per day" or "per month". What should determine what time unit to use in a model?

b) Why do you have to measure all in- and outflows to *all* stocks in a model with the same time unit (for example per second or per minute). Hint. Recall the difference equation used in the simulation software (Euler) with its one and only Timestep (*dt*) that is used to calculate the development of all stocks from one point in time to the next.