

SEMINAR 1

MOTION ANALYSIS UNPLUGGED

Course objectives

- The ability to describe the characteristics of a stock and a flow in a system diagram.
- The ability to draw, explain and apply the system diagram that describes motion in different situations of motion.
- The ability to switch between representations (story, table, system diagram, graphs) when describing motions.

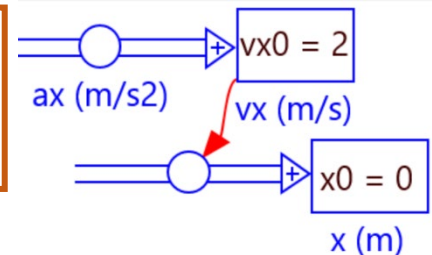
Motions can be made 'visible' in various ways. You can physically perform the motion, describe it, express it in formulas, create tables and diagrams and use a system diagram. In class, you will practice with the different representations of three different motions.

0. Put the date, class, course number and the names of the creators on the poster. **NB Please, DON'T write on the back, if necessary get a new poster.**

Situation 1 (together)

Motion description (1)

You are walking with a constant velocity of 2 m/s. At time $t = 0$ s you pass the point $x = 0$ m. The motion lasts 4 seconds and corresponds to the system diagram shown here.



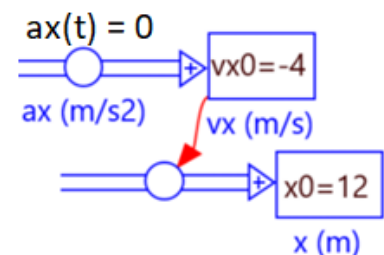
1. Include the following representations on your poster:
 - story
 - system diagram
 - table
 - three graphs $x(t)$, $vx(t)$ and $ax(t)$

Situation 2

Motion description (2)

For situation 2, you only get the system diagram. The motion lasts 5 seconds.

On the basis of this, are you able to answer the following questions?



2. Include the following representations on your poster:
 - story
 - system diagram
 - table
 - three graphs $x(t)$, $vx(t)$ and $ax(t)$

Situation 3

Situation 3	System	Table	Diagrams																												
At time $t = 0$ s you begin from a stationary position $x = 0$ m with a forward acceleration of 2 m/s^2 for the duration of 5 seconds.		$t(s), ax \text{ (m/s}^2\text{)}, vx\text{(m/s)}, x\text{(m)}$ <table border="1"> <thead> <tr> <th>t</th> <th>0</th> <th>1</th> <th>2</th> <th>3</th> <th>4</th> <th>5</th> </tr> </thead> <tbody> <tr> <td>a</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>v</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>x</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	t	0	1	2	3	4	5	a							v							x							
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Hint	The position x at time t is equal to the area under the $v(t)$ -graph (at the given time).																														

3. Include the following representations on your poster:

- story
- system diagram (with values)
- table
- three graphs $x(t)$, $vx(t)$ and $ax(t)$

Submit the poster to your teacher at the end of class.

Stock	Flow
<p>A stock or state variable represents a specific quantity. It is a supply of something.</p> <p>Stocks can only change through inflow or outflow.</p> <p>At each time unit, it is determined whether the supply changes, either by inflow or outflow.</p> <p>A stock requires an initial value and a (net) flow.</p>	<p>A flow or flow variable represents the change in stock per time unit.</p> <p>The flow determines how the stock changes per time unit. $\Delta Stock = Flow \cdot \Delta t$</p> <p>The unit of flow is the unit of stock per the unit of time.</p>

SEMINAR 2 MOTION ANALYSIS WITH THE COMPUTER

During this seminar you will use the computer to analyse motions.

Course objectives

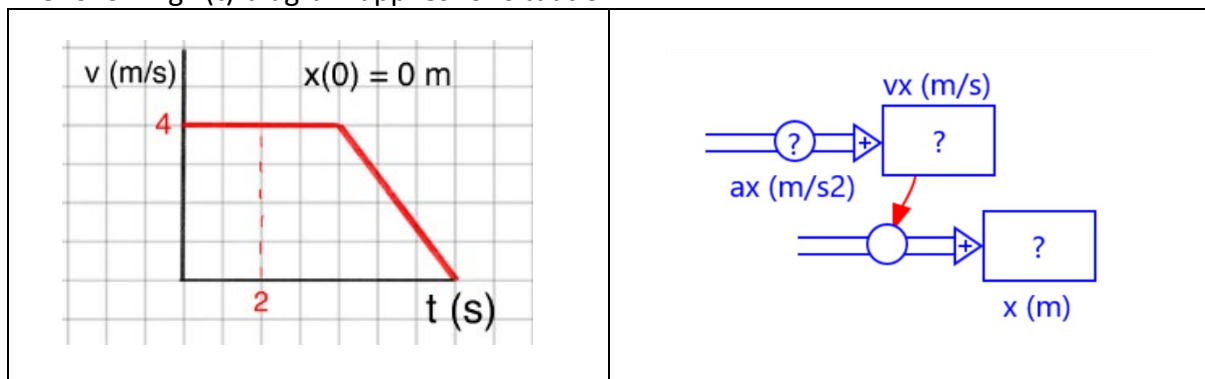
- The ability to construct the system diagram that describes motion and run it in Coach.
- The ability to use the model for different motion situations.
- The ability to create $a_x(t)$ -, $v_x(t)$ - and $x(t)$ -graphs using the model.
- The ability to explain model and graphs using the motion description.

0. Put the date, class, course number and the names of the creators on the poster. **NB DON'T write on the back, if necessary get a new poster.**

Execute the following assignments on posters (A3 sheets). **NB DON'T write on the back, if necessary get a new poster.**

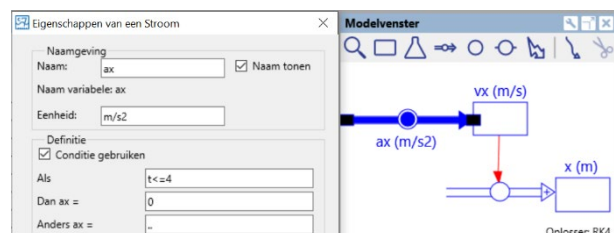
SITUATION 1

The following $v(t)$ -diagram applies for situation 1.



1. **Motion description** Describe the motion.
2. **Prediction.** Predict the general shape of the $a_x(t)$ - and $x(t)$ -diagram with a sketch.
3. Complete the **system diagram** with initial values and properties of the acceleration.

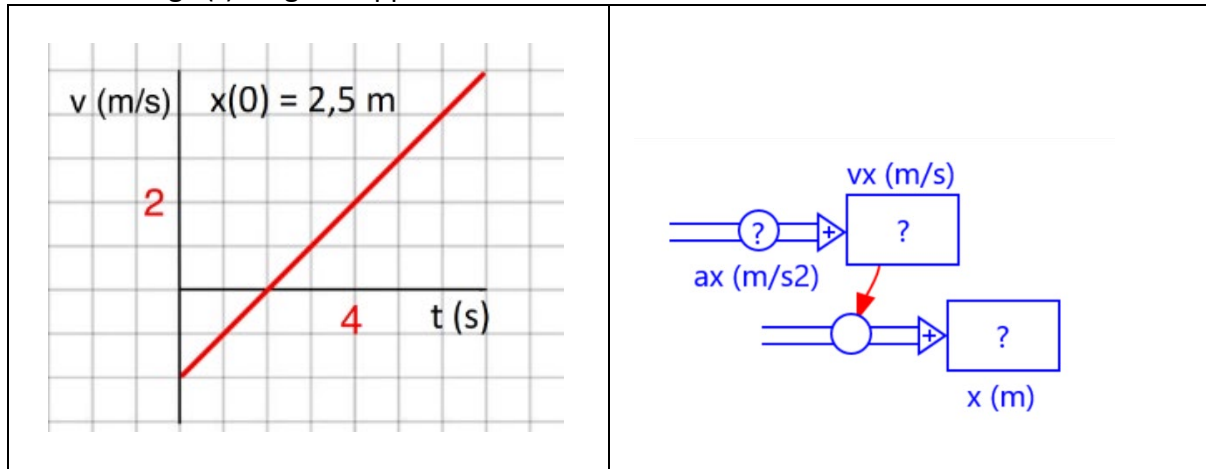
Use Coach7 (modellieren) to create and run the model. When entering the properties of the acceleration ax (m/s²), you can click on *Conditie gebruiken*.



4. Draw or show a screenshot of the $a_x(t)$ -, $v_x(t)$ - and $x(t)$ -diagrams created with the model. Were your predictions correct?
5. Analyse the graphs: for each segment of the graph, identify the type of motion (standing still, constant speed, accelerating, decelerating) and explain how you can see that in each of the graphs.

SITUATION 2

The following $v(t)$ -diagram applies for situation 2.



1. **Motion description** Describe the motion.
2. **Prediction.** Predict the general shape of the $a_x(t)$ - and $x(t)$ -diagram with a sketch.
3. Complete the **system diagram** with initial values and properties of the acceleration.
4. Draw or show a screenshot of the $a_x(t)$ -, $v_x(t)$ - and $x(t)$ -diagrams created with the model. Were your predictions correct?
5. Explain the relationship between the graphs.

SITUATION 3 A car accelerating

A car accelerates for 4 seconds from a stationary position with an acceleration of 4 m/s^2 . After which it continues driving for $5,0 \text{ s}$ with constant velocity.

6. **Prediction.** Predict the general shape of the $a_x(t)$ -, $v_x(t)$ - and $x(t)$ -diagram with a sketch.
7. Draw the system diagram.
Show **which (initial) values** you need.

Use Coach7 (modellereen) to create and run the model.

8. Show a screenshot of the $a_x(t)$ -, $v_x(t)$ - and $x(t)$ -diagrams created with the model. Were your predictions correct?
9. Explain the relationship between the graphs.
10. What distance has car (A) travelled?
11. Demonstrate with your model whether a car (B) that accelerates for nine seconds with an acceleration of $2,67 \text{ m/s}^2$ travels farther, the same distance, or less far than A.

SEMINAR 3 FORCE ANALYSIS

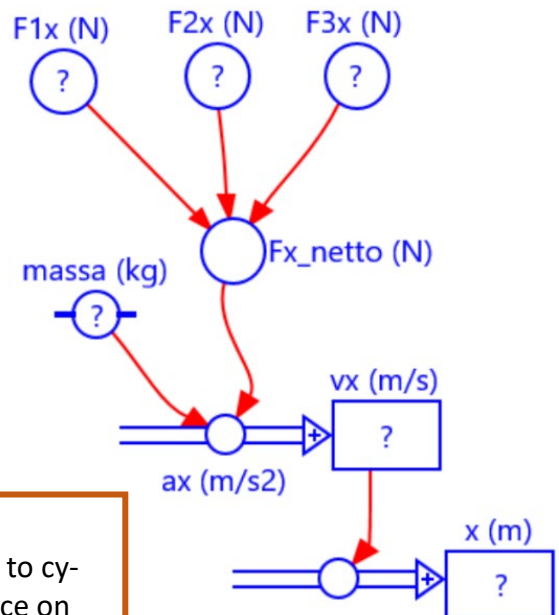
Course objectives

- The ability to describe Newton's first two laws.
- The ability to explain the system diagram for the relationship between force and motion and connect it to Newton's laws.
- The ability to construct the system diagram that describes several dynamic situations and run it in Coach.
- The ability to explain model and graphs.

FORCE ANALYSIS

"If you know forces, mass and initial values, you know the motion."

The system diagram (SD) shown here illustrates the relationship between force and motion.



FORCE ANALYSIS IN THREE MOTION SITUATIONS

Include the following exercises on your poster:

Situation A Amira cycles

Amira departs from home with a velocity of 14,4 km/h to cycle to school, which is 2,4 km away. The propulsion force on the bike is 120 N. The total friction force is also 120 N. The mass of Amira + bike is 60 kg.

1. Sketch Amira on her bicycle and forces.
2. Draw the system diagram with constants, variables and initial values.
3. Create and run the model. Show the following diagrams in Coach: the forces as a function of the time (in one diagram), the $ax(t)$ -, $vx(t)$ - and the $x(t)$ -diagram. Sketch the development of the graphs on your poster.
4. Write a brief explanation for each graph.

Situation B Boris also cycles

Starting from rest, Boris exerts a propulsion force of 243 N for 4.72 seconds, after which he keeps his legs still and coasts. Throughout the entire motion, the frictional force is 123 N. The mass of the bike + Boris is 80 kg.

5. Sketch Boris on his bicycle and forces.
6. Draw the system diagram with constants, variables and initial values.
7. Create and run the model. Show the following diagrams in Coach: the net force and the $ax(t)$ -, $vx(t)$ - and the $x(t)$ -diagram. Sketch the development of the graphs on your poster.
8. After how many seconds does Boris come to a stop? What distance has he travelled at that moment?
9. Write a brief explanation for each graph.

Situation C A volleyball drops

A volleyball with a mass of 270 grams and a circumference of 66 cm drops from the roof of an apartment building (height = 70 m).

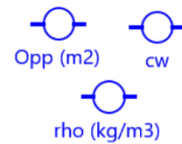
The following formula applies to the air friction force.

$$F_{w_lucht} = \frac{1}{2} \cdot c_w \cdot \rho \cdot Opp \cdot v_y^2$$

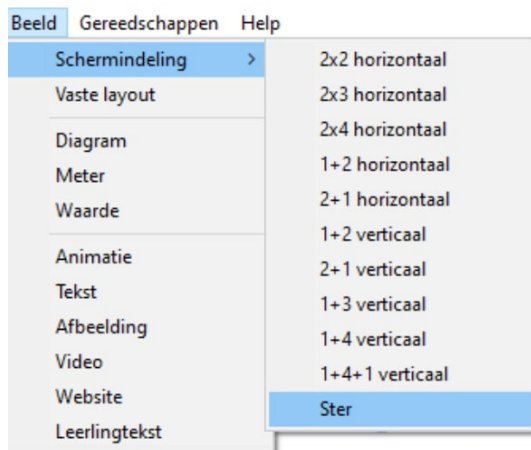
In this c_w is the friction coefficient ($c_w \sim 0,50$), ρ the air density ($1,293 \text{ kg/m}^3$) and Opp the frontal area ($0,0347 \text{ m}^2$).

10. Sketch volleyball and forces.
11. Sketch the system diagram with constants, variables and initial values.
12. Create and run the model. Show the following diagrams in Coach: the forces as a function of the time (in one diagram), the $ax(t)$ -, $vx(t)$ - and the $x(t)$ -diagram. Sketch the development of the graphs on your poster.

Hint: make sure to list the constants separately, so that you can reuse and modify the model for the assignment in SEMINAR 4.

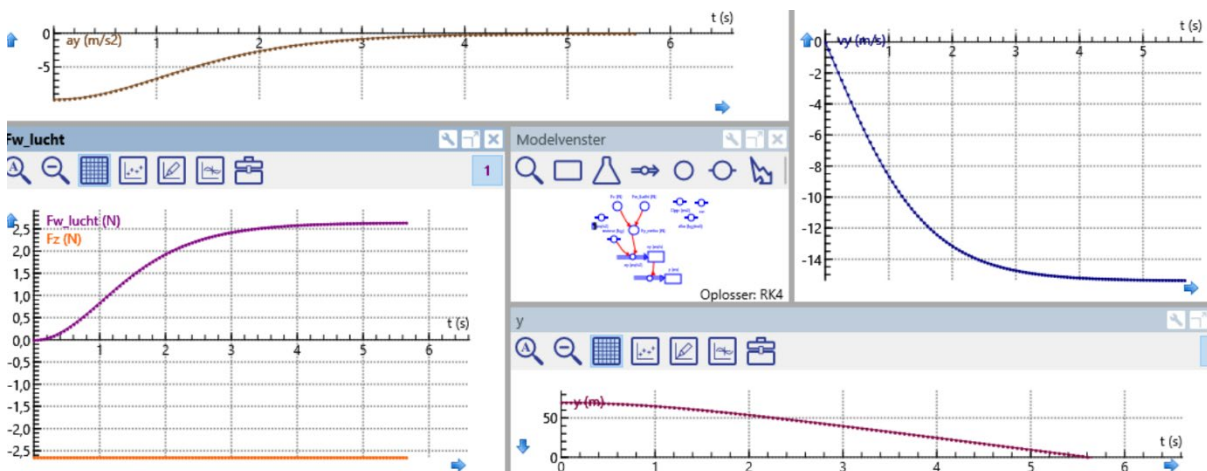


13. Write a brief explanation for each graph.



Hint. When you have an image, set the display to 'ster'. This way you can show four diagrams (the corners) + the model in the center.

Your screen will look something like the following figure.



Course objectives

- The ability to apply the four phases of computational problem solving ◦ *Define* ◦ *Abstract* ◦ *Solve and* ◦ *Interpretate* in practice using a real-world problem.

A manufacturer claims to have developed a super-safe parachute. Its strengths, he says, are the large frontal area and the quick opening. This guarantees a safe landing, he insists. It is your job to investigate the claims of the manufacturer.



Go through the following four steps. Write down answers on your poster.

• **1 Define**

Describe the question.

- What question do you wish to answer, what problem do you want to solve? Why?
- What decisive concepts and quantities play a part? (How do you measure safety)
- What time frame should you consider?

• **2 Abstract**

Convert the question into a computational form

- Describe the suspected behaviour.
- Create a system diagram (Stock-Flow-map)
- Construct the model, specify the rules governing the flows and auxiliary variables
- Determine the values of constants and initial values.
- Review the settings of the model and make decisions regarding time, stop condition, integrating method and time interval

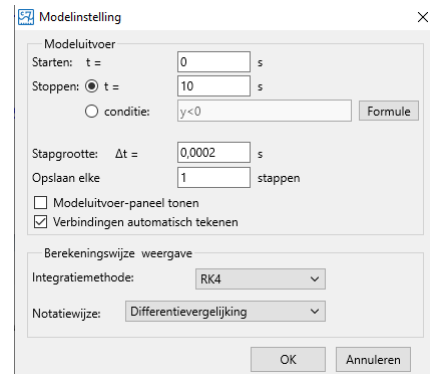


Figure1 potential settings for the model.

The opening of the parachute

You have learnt how to create a model of a fall with air friction, but how do you account for a parachute that opens during the jump?

You can incorporate the opening of the parachute as follows. Consider the surface area of the parachute as stock. This makes the change of the surface area per unit of time the flow.

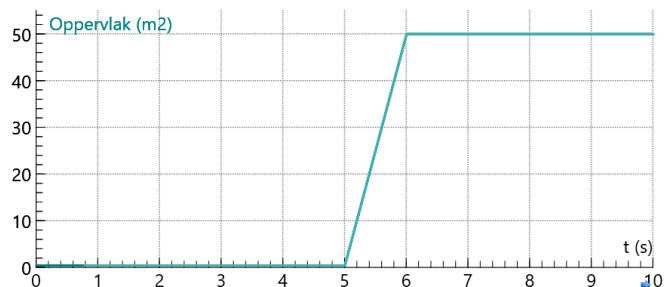
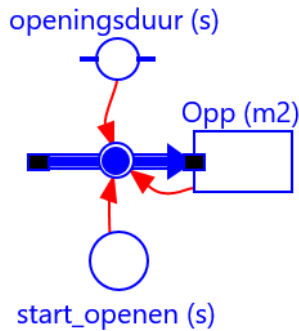


Figure 1 Frontal surface area as function of time of a parachute that in 1 second increases from 0,5 to 50 m².

The flow is calculated with
$$\frac{\Delta Opp}{\Delta t} = \frac{Opp_{end} - Opp_{begin}}{\text{duration of opening}}$$



Naamgeving	
Naam:	Flow_Opp <input type="checkbox"/> Naam tonen
Naam variabele:	Flow_Opp
Eenheid:	m2/s
Definitie	
<input checked="" type="checkbox"/> Conditie gebruiken	
Als	$(t < \text{start_openen})$ Of $(\text{Opp} > = 50)$
Dan Flow_Opp =	0
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- **3 Solve**

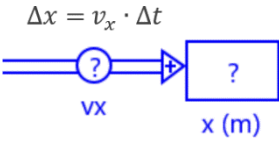
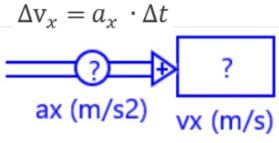
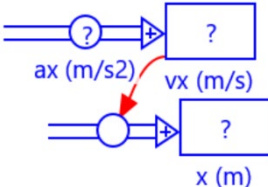
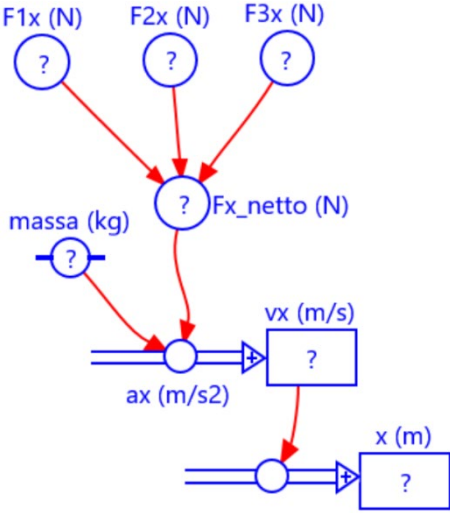
Test your model and find computational answers






- Run the model.
- Does the model behave according to your expectations (for example: do you fall down instead of up)?
- Illustrate which graphs you want to display. Which graphs do you need to answer the safety issue?
- Are you satisfied with the size of the time steps? Focus especially on moments when rapid changes occur. Are these monitored with small enough time steps?
- Is there a reason to change anything stopcondition, initial values or other parameters?

- **4 Interpret**

Evaluate and express your findings in technical terms

- Formulate an answer to the question. Use graphs to support your answer.
- Does this answer correspond to your expectations?
- What are the limitations of the answer?
- What do you advise the manufacturer?
- Is additional research necessary?

System diagram	Description
	<p>Flow (velocity) is the change of stock (position) per unit of time.</p> $v_x = \frac{\Delta x}{\Delta t} \iff \Delta x = v_x \cdot \Delta t$ <p>The new position $x_{t+\Delta t}$ is the old position x_t plus the change in position Δx.</p> $x_{t+\Delta t} = x_t + v_x \cdot \Delta t$
	<p>Flow (acceleration) is the change of stock (velocity) per unit of time.</p> $a_x = \frac{\Delta v_x}{\Delta t} \iff \Delta v_x = a_x \cdot \Delta t$ <p>The new velocity $v_{t+\Delta t}$ is the old velocity v_t plus the change in velocity Δv.</p> $v_{x,t+\Delta t} = v_{x,t} + a_x \cdot \Delta t$
	<p><i>“ If you know the acceleration and initial values, you know the motion.”</i></p> <p>The acceleration determines the change in velocity. The velocity determines the change in position. For velocity and position, the initial values must be provided.</p>
	<p><i>“ If you know forces, mass and initial values, you know the motion.”</i></p> <p>In dynamics, force and motion are combined. The net force on an object in a certain direction determines the acceleration of the object in that direction with $a_x = \frac{F_{x_netto}}{m}$, in which m is the mass of the object.</p>

Building block	Description
<p>Stock, supply or state variable.</p> 	<p>Stocks or state variables represents a specific quantity, a supply. This can be real supplies, like the number of cars in a factory, but it can also be more abstract quantities, such as velocity or customer satisfaction. Stocks can only change through inflow or outflow. No other influence is possible.</p> <p>A stock is an integrator or accumulator: per time step, something is added, something flows out, or the quantity remains unchanged. In this last case, the netto flow is equal to zero.</p>
<p>Flow or flow variable</p> 	<p>Flow or flow variables determine how a stock changes. 'Flow' symbolizes change: flowing water from a tap, but also birth and death in a population, changes in substance concentrations, changes in the position and velocity of an object, etc.</p> <p>A flow is always connected to a stock. Direction is important here: incoming flows contribute to a an increase in the stock, while outgoing flows contribute to a decrease.</p> <p>A flow is a differentiator. The net flow allows the change in stock to be determined at each time step.</p> <p>The unit of flow is the unit of stock per second.</p>
<p>Auxiliary variable</p> 	<p>Auxiliary variables are additional variables that are not state variables (and therefore have no flow arrow). When studying motion, an auxiliary variable can be used to calculate the net force.</p>
<p>Constant</p> 	<p>A constant is a variable that does not change when running the model. No other variables can be connected to constants.</p>
<p>Connection arrow (red)</p> 	<p>A connection arrow shows the relationship between elements. The arrow between two variables indicates that the variable at the point of the arrow depends on the variable at the start of the arrow.</p>
<p>Model settings</p>	