

Force and motion

The essence of dynamics

DynaLearn level 4 | Version 1.0

Summary	
In this lesson, you will first learn about the relationship between the quantities net force, acceleration, and velocity. In the second part of the lesson, you will learn how gravity and air resistance together determine the net force of a falling object and how velocity and air resistance are related. You will learn about the relationship between these quantities by creating a model in DynaLearn.	
Given name	
Surname	
Class	
Date	
Comments by teacher	

1. Starting DynaLearn

There are multiple ways to log in. Use one of the two options below.

Via a code:

1. **Go** to DynaLearn (<https://create.dynalearn.nl/>).
2. **Click** on 'login with code' in the bottom left corner.
3. **Enter** the project code and your (school) email address.
4. **Copy** the code from the confirmation email from the sender dynalearn.nl (see spam folder) and **fill** in the other details.
5. **Log in** to DynaLearn and **check** if the login was successful (see 'Let's check!').

By invitation:

1. **Copy** the login code from the sender's invitation email dynalearn.nl.
2. **Go** to Dynalearn (<https://create.dynalearn.nl/>).
3. **Log in** to DynaLearn and **check** if the login was successful (see 'Let's check!').

Let's check!

After logging in, you will automatically be taken to the white workspace of the assignment. You can recognize it by the gray question mark on the right side of the screen . Is the question mark missing? First, do:

- In Dynalearn, click . **Click** 'Select norm model'.
- **Choose** 'Force and motion' and **press** 'Load'.

Save model file and start:

1. **Click** on the  top left. Change the name to 'Force and motion' and **click** 'Save'.
2. How do you get started? **Just follow** the steps in this lesson plan. Please note! You can't skip any steps. Ask for help if you can't figure out a certain step. The video feature  in Dynalearn shows how to make a model ingredient. The **sources** contain information about the water potential and the **boxes** contain a brief explanation of the model ingredient. Put a check mark \checkmark by the number of a step you've performed. This way, you can keep track of where you left off.

1. Net force and acceleration

1. [View Source 1.](#)

$$acceleration(a) = \frac{net\ force\ (F_{res})}{mass\ (m)}$$

Source 1. Newton's second law states: the acceleration (a) of an object is **positively proportional** to the resultant force (F_{res}): if force increases (decreases), then acceleration also increases (decreases). The equation reflects this proportionality. In this lesson, we start with objects whose mass (m) does not change during movement.

2. [Read Box 1.](#)

Box 1. Entity and quantity

An entity  is usually a physical thing in a system (e.g., car, human).

A quantity  is a measurable property of an entity (e.g., temperature, length).

3. [Create](#) the entity *Object* (see  → .
4. [Create](#) the quantity *Net Force (F_{res})* of the entity *Object* (see  → .
5. [Create](#) the quantity *Acceleration (a)* of the entity *Object*.
6. [Read Box 2.](#)

Box 2. Change of a quantity.

A quantity  can change. This is indicated by $\frac{\delta}{\downarrow \uparrow \emptyset}$. The delta symbol (δ) is the mathematical sign for change (also called the derivative). The down arrow (\downarrow) is a decrease, the zero (\emptyset) is constant, and the up arrow (\uparrow) is an increase.

7. Read Box 3.

Box 3. A proportional relationship.

In a proportional relationship, a change in the quantity that is the **cause** causes a **change** in the quantity that is the **effect**. In Dynalearn, **positive** and **negative proportional** relationships between quantities are indicated with P^+ and P^- respectively.

8. The relationship between *Net Force (Fres)* and *Acceleration (a)* is **proportional** (see also

Source 1). **Create** this relationship (see  → ). Pay attention to the direction of the arrow (cause → effect).

9. Read Box 4.

Box 4. Help function.

If the question mark  or an ingredient in your model  is red, then something is wrong. Click the question mark  for a hint. Then click on a number, for example  to see where the error is in your model. Only use the question mark if you can't figure it out yourself!

10. Read Box 5.

Box 5. An exogenous influence.

If you want a quantity to decrease, remain stable or increase throughout the simulation, you must add an external influence (an exogenous influence) to the quantity.

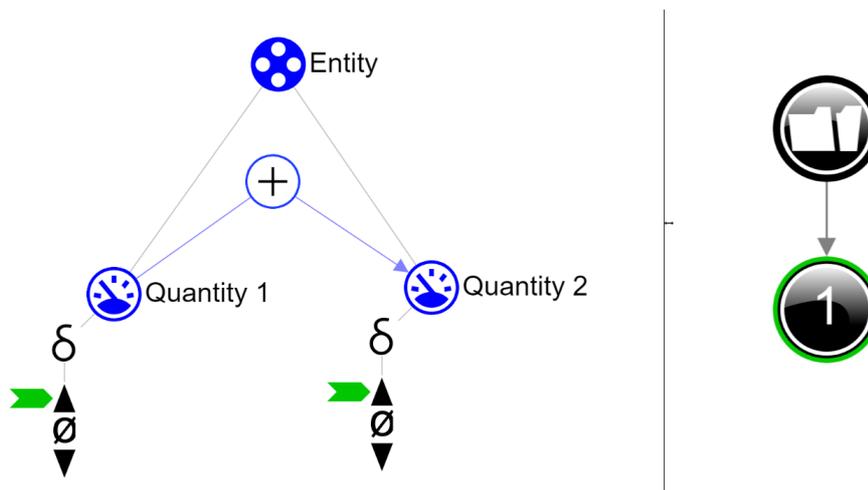
11. **Set** as initial value:

- a. **Create** an exogenous influence (see  → ) of type **descending**  for *Net Force (Fres)*. This is because it is not specified by which forces the *Net Force (Fres)* is determined.

12. Read Box 6.

Box 6. Read the outcome of a simulation.

After starting a simulation (with ) , a window appears on the right in which the possible states of the system are indicated. There is one possible state in this example .



You can click on the state to view the outcome. The condition then acquires a green edge. In the model, the change for this state is indicated by a green arrow  . The model shows that in state  Quantity 1 increases and that therefore Quantity 2 also increases.

13. Start the simulation  . Also, investigate what happens when *Net Force (Fres)* is constant or decreasing. To do this, change the exogenous influence to type **constant** and **increasing** respectively. Describe below what the cause-effect relationships are that take place (cross out wrong answers):

- If the net force decreases, then acceleration will *decrease/remain the same/increase*
- If the net force remains the same, then acceleration will *decrease/remain the same/increase*
- If the net force increases, then acceleration will *decrease/remain the same/increase*

2. Correspondence between net force and acceleration

1. See Source 2.

Source 2. According to Newton's second law (see Source 1):

- If there is **no** net force, then there is **no** acceleration.
- If there is **a** net force, then there is **an** acceleration.

2. Read Box 7.

Box 7. Quantity space.

A newly created quantity  does not yet have a **quantity space**. By adding a quantity space you can indicate which values a quantity can take on. A quantity space consists of points (■) and intervals (▬).

- A point value is only one value. For example, a *boiling point*. A special point is the zero point, for which there is a separate symbol (\emptyset) in Dynalearn.
- An interval is a set of values. The liquid phase of a substance is an example of an interval. In the case of water, the interval 'liquid' contains all values between 0 °C and 100 °C. The values 0 °C and 100 °C are respectively the '*melting point*' and the '*boiling point*' between which the interval 'liquid' is located.

3. Create a quantity space (see  → ) for the quantities *Net Force (Fres)* and *Acceleration (a)* with a zero point (\emptyset) and above that an interval (+). It will look like this:



***Please note! Acceleration can also have a negative direction with regard to the motion (this will cause a deceleration). We leave this out of the model.**

The current model does **not** yet stipulate that the above values of net force and acceleration always occur together. This is shown by the following simulation.

4. Set as initial values (see  → ):

- Net force (Fres)* is positive (+)  . This is the **value** of the quantity.
- Acceleration (a)* is positive (+)  . This is the **value** of the quantity.
- The exogenous influence for *Net Force (Fres)* is of the type **descending** . Thus, *net force (Fres)* decreases. This is the **change** of the quantity.

5. **Start** the simulation. Which final state is not possible according to Newton's second law?

Final state ... is not possible because ...

6. **Read** Box 8.

Box 8. Correspondence

In a system, it can happen that **all** values of a range of values of a quantity correspond to the values of a range of values of another quantity. You can then make a **correspondence between the quantity space** of both quantities.

7. **Create** a **correspondence** of type **directed** (see  → ) between the quantity spaces of *Net Force (Fres)* and *Acceleration (a)*.
8. You can keep the model organized by using the buttons at the bottom of the screen. **Click**  to align everything neatly. **Click**  to make your model fit the screen. Use these buttons regularly.
9. **Set** as initial values:
- Leave initial values as in the previous simulation.
10. **Start** the simulation. How many states are possible now?

Number of states:

11. **Read** Box 9.

Box 9. Help function.

If the explanation mark appears , something is wrong during the simulation. Click on the explanation mark  for a hint. Then click on a number, for example , to see where the error is in your simulation.

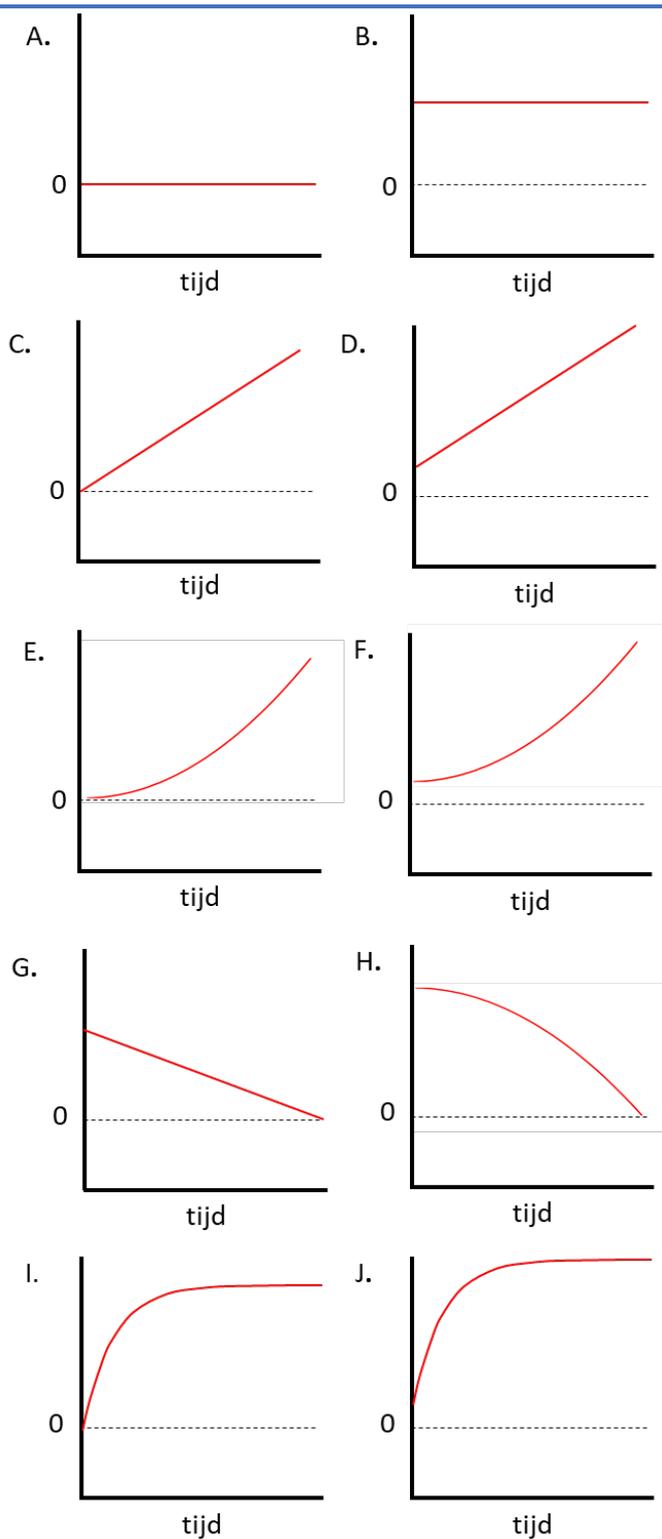
12. **Click**  and then . **Remove** the unnecessary initial value.

13. Source 3 (next page) contains several graphs (A to J) that can be applied to the change of a certain quantity at the given initial situation. Investigate what happens to the net force and acceleration at the initial values below **using simulations** of the model. Always choose the graph that fits best.

1. **Set initial values:** The net force is positive (+)  $\neq 0$ and remains constant . **Start** the simulation.
 - a. The graph that best matches the net force on the object is:
 - b. The graph that best matches the acceleration of the object is:

2. **Set initial values:** The net force is zero (0) and remains constant. **Start** the simulation.
 - a. The graph that best matches the net force on the object is:
 - b. The graph that best matches the acceleration of the object is:

3. **Set initial values:** The net force is zero (0) and continues to **increase linearly**. **Start** the simulation.
 - a. The graph that best matches the net force on the object is:
 - b. The graph that best matches the acceleration of the object is:



Source 3. Graphs. The x-axis shows the time. On the y-axis you can place the quantities: net force, acceleration, velocity, or distance. A and B = constant, C and D = ascending linear, E and F = increasing increase, G = descending linear, H = increasing decrease, I and J = decreasing increase.

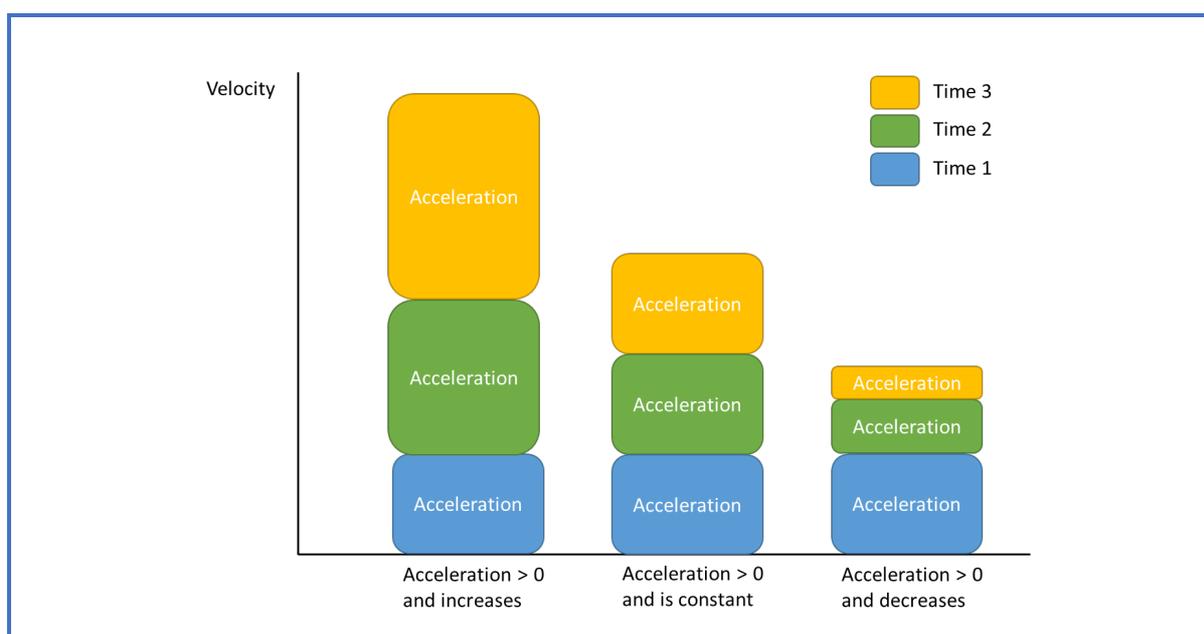
3. The Relationship Between Acceleration and Velocity

1. [View Source 4.](#)



Source 4. Newton's first law states: if there is **no net force** acting on an object, it will always continue to move at a constant velocity (this can also be 0 m/s). Often this law is explained by using a spaceship as an example. Far out in space, there are no forces acting on the spaceship. If the spacecraft briefly turns on its engine to accelerate and then turns off, the velocity will remain constant. There is nothing to stop the spaceship, but also nothing to make it go faster because the engine is off. However, the same is true of all objects in motion on Earth. The train on the right in the figure above also has a **net** force of 0 because the forward force and the counteracting force are the same. If the train is already moving, the velocity will also remain constant.

2. [View Source 4.](#)



Source 4. You've just learned that the relationship between force and acceleration is **proportional**. The relationship between acceleration and velocity (v) is **not** proportional. After all, even if the acceleration is constant or decreasing (but is greater than 0), the velocity will increase. In the figure above, this is shown for 3 situations. From the figure you can conclude that the velocity will always increase if the acceleration is positive. In **the middle** situation, the acceleration is constant, so the velocity will increase by a constant amount. This is called a **uniform linear motion**. In the left and right situations, there is a **non-uniform linear motion**. In the left situation, acceleration increases, causing the velocity **to increase faster and faster**. In the situation on the right, the acceleration decreases (but remains greater than 0) so that the velocity **increases more and more slowly**. The fact that a decreasing acceleration still causes an increase in velocity is often considered difficult. However, the **velocity** of an object **decreases only** if the acceleration has a **negative direction with regard to the motion** (this is not part of the model).

3. **Create** the quantity *Velocity* (v) for the entity *Object*.

4. **Read** Box 10.

Box 10. An influence relationship.

Some quantities in a system are processes. A process is a quantity that adds or removes something to the system **per unit of time** (e.g. per second, per year). Simple examples of processes that **add** something are: (i) water from a tap that flows (L/s) into a bath and (ii) an oven that provides a certain power (J/s) to heat a dish. (iii) the amount of tax paid every year (€/y). The outflow (L/s) of water through the drain is an example of a process that **removes** something from the system.

The relationship between a process and another quantity is called an **influence** ($\textcircled{I+}$ or $\textcircled{I-}$) in Dynalearn. In this type of relationship, the **value** of the process determines the **change** in the quantity on which an influence is exerted.

5. Thus, the relationship between *Acceleration* (a) and *Velocity* (v) is **not proportional** but of type of **influence**. Acceleration is a process (m/s²). **Make** this relationship (see  \rightarrow ).

6. **Create** a quantity space for the quantity *Velocity* (v) with a zero point (\emptyset) and above that an interval (+).
7. Click  to align everything neatly. Click  to make your model fit the screen.
8. Investigate what happens to the acceleration and velocity in the initial situations below using simulations. Always choose the graph (Source 3: A to J) that fits best and determine whether the velocity in the final state is uniform or non-uniform (cross out wrong answer).

1. **Set initial values:** The **net force** on the object is zero (0)  and is constant , the object has a positive initial **velocity** (+) . **Start** the simulation.
 - a. The graph that best matches the acceleration on the object is:
 - b. The graph that best matches the velocity of the object is:
 - c. In the final state, the velocity is *uniform/non-uniform*.
2. **Set initial values:** The **net force** on the object is zero (0) and increases linearly, the object has no initial **velocity** (0). **Start** the simulation.
 - a. The graph that best matches the acceleration on the object is:
 - b. The graph that best matches the velocity of the object is:
 - c. In the final state, the velocity is *uniform/non-uniform*.
3. **Set initial values:** The **net force** on the object is positive (+) and is constant, the object has no initial **velocity** (0). **Start** the simulation.
 - a. The graph that best matches the acceleration on the object is:
 - b. The graph that best matches the velocity of the object is:
 - c. In the final state, the velocity is *uniform/non-uniform*.

4. Distance

An object with velocity will travel a distance(s).

1. **Create** the quantity Distance (s) for the entity *Object*.
2. The relationship between *Velocity* (v) and *Distance* (s) is **not proportional** but of type of **influence**. Velocity is a process (m/s). **Make** this relationship.
3. **Create** a quantity space for the quantity *Distance* (s) with a zero point (\emptyset) and above that an interval (+).
4. Investigate what happens to the velocity and distance in the starting situations below using simulations of the model. Always choose the graph (Source 3: A to J) that fits best.

1. **Set the initial values:** The **net force** on the object is zero (0) $\rightarrow \emptyset^+$ and is constant \rightarrow , the object has a positive initial **velocity** ($+$) $\rightarrow \emptyset^+$, and the **distance** traveled is zero (0) $\rightarrow \emptyset^+$. **Start** the simulation.

- a. The graph that best suits the velocity of the object is:
- b. The graph that best suits the distance of the object is:

2. **Set the initial values:** The **net force** on the object is positive ($+$) and is constant, the object has no initial **velocity** (0), and the **distance** traveled is zero (0). **Start** the simulation.

- a. The graph that best suits the velocity of the object is:
- b. The graph that best suits the distance of the object is:

3. **Set the initial values:** The **net force** is positive ($+$) and decreases linearly, the object has an initial **velocity** ($+$), and the **distance** traveled is zero (0). **Start** the simulation.

- a. The graph that best suits the velocity of the object is:
- b. The graph that best matches the distance of the object is not shown in source 3. Make the sentence correct (cross out wrong answers):

In the beginning, the distance will [choose:] *uniformly/non-uniformly* [choose:] *decrease/remain the same/increase*. Finally, the distance will [choose:] *uniformly/non-uniformly* [choose:] *decrease/remain the same/increase*.

5. Falling object, gravity and air resistance

When an object falls, two forces determine the net force: gravity (F_g) and air resistance (F_{air}). The air resistance is caused by the collision between the object and the particles in the air (i.e. nitrogen, oxygen, etc.).

1. **Create** the quantities *Gravity* (F_g) and *Air resistance* (F_{air}) of the entity *Object*.
2. **Create** a quality space for the quantities *Gravity* (F_g) and *Air resistance* (F_{air}) with a zero point (\emptyset) and above that an interval (+).
3. **Make** the right type of relationship between *Gravity* (F_g) and *Net force* (F_{res}). Tip: An object that gets closer and closer to the Earth will experience more and more gravity and the net force on the object will increase.
4. **Make** the right type of relationship between *Air resistance* (F_{air}) and *Net force* (F_{res}). Tip: The air resistance experienced by a falling object has the opposite effect of gravity: the more air resistance, the smaller the net force.
5. **Make** the right type of relationship between *Velocity* (v) and *Air resistance* (F_{air}). Tip: The more velocity an object has, the more air resistance it experiences. At a constant velocity, the air resistance is also constant.

Now you are going to indicate in the model that:

$$\text{net force}(F_{net}) = \text{gravity}(F_g) - \text{air resistance}(F_{air})$$

Thus, we argue that gravity, despite being directed downwards, is a positive force.

6. **Make** the calculus (see  \rightarrow ):

$$\text{Gravity}(F_g) - \text{Air resistance}(F_{air}) = \text{Net force}(F_{res})$$

7. **Click**  to align everything neatly. **Click**  to make your model fit the screen.

8. **Set** as initial values (we assume a situation in which an object is released from a certain height):

- Remove** the exogenous influence  from quantity *Net force* (F_{res}).
- Gravity* (F_g) is positive (+)  and constant . Within the Earth's atmosphere, we can consider gravity to be constant.
- Velocity* (v) is zero (0) .
- Air resistance* (F_w) is zero (0) .

9. **Start** the simulation. Make the sentences below correct (cross out wrong answers).

Status 1

The net force in state 1 is $0/+$ because the *gravity/air resistance* is greater than the *gravity/air resistance*. The net force decreases because the air resistance *decreases/stays the same/increases* and the gravitational force *decreases/stays the same/increases*. As the net force decreases, the acceleration will *decrease/stay the same/increase*. The velocity *decreases/stays the same/increases* because the acceleration *decreases/stays the same/increases/is zero/is positive*. Because the velocity *decreases/stays the same/increases/is zero/is positive*, the air resistance will *decrease/stay the same/increase*.

Condition 2

In state 2, the air resistance is $0/+$ and it *decreases/stays the same/increases*. The net force is $0/+$ because the force of gravity *is less/equal to/greater than* the air resistance. The acceleration decreases but is positive, so the velocity *decreases/remains the same/increases*. As a result, the air resistance *decreases/remains the same/increases*.

Condition 3

As the velocity increases, the distance will *decrease/stay the same/increase*.

Condition 4 (end state)

In state 4, the net force is $0/+$ because the force of gravity *is less/equal to/greater than* the air resistance. The acceleration is $0/+$ because the net force is $0/+$. Because the acceleration is $0/+$, the velocity will *decrease/stay the same/increase*. Because the velocity is proportional to the air resistance, the latter will *decrease/remain the same/increase*.

The graph that best suits the velocity of the object during the fall is:

Conclusion:

From an object that falls, the acceleration will *decrease/increase* and the velocity will *decrease/increase* until the air resistance *is less/equal to/greater than* gravity. The velocity of the falling object then *decreases/is constant/ increases*.