Force and motion

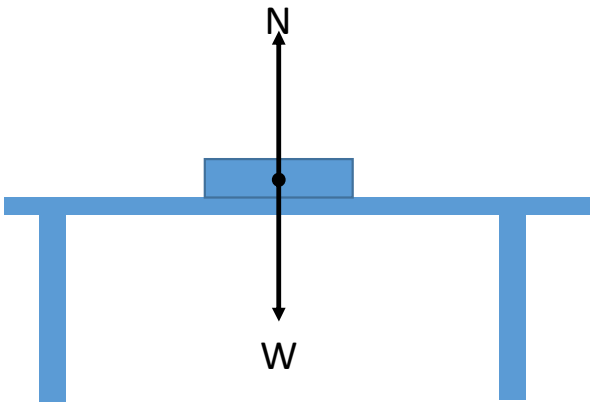
In the previous section we studied **kinematic** which is the study of objects in motion disregarding the force that initiated the motion. However, in this section we pay our attention to the force that causes the motion. In particular, we will study the **dynamics** of an object, which is the study of motion of an object under the action of forces. To analyse the principles of dynamics, we are going to introduce some new concepts which are **mass, force and Newton's laws**.

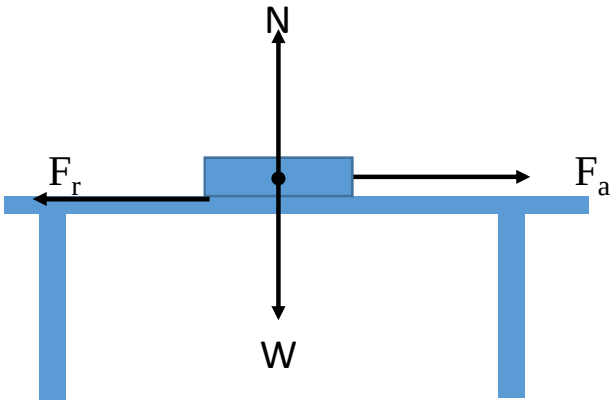
Mass is defined as a measure the amount of matter contained in an object.

A **force** may be understood, informally, as a 'push' or 'pull'. However, scientifically, a force is defined as an interaction between two objects or between an object and its environment. There are different types of force and they will be defined later. However the following force are defined here for a sake of introducing the concept of balanced and unbalanced forces.

- **Weight** is an attractive force exerted by the earth on objects which are on or close to the earth's surface.
- **Normal** is a perpendicular force exerted by a surface on the object in contact with the surface.
- **Applied** force is defined as an attractive or repulsive force exerted on an object.
- **Friction** is the force opposing the motion of an object in contact with the surface.

Balanced and unbalanced forces

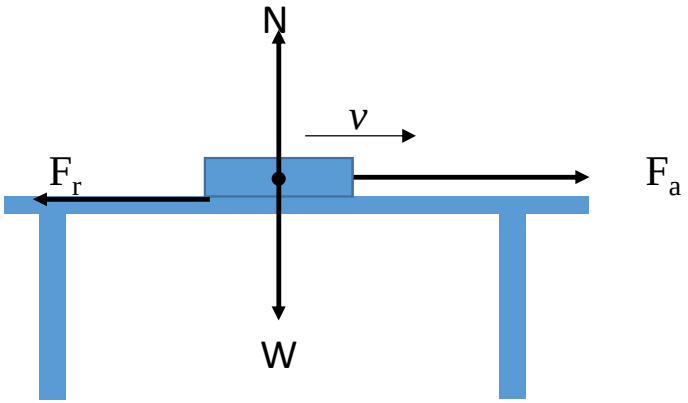




The book does not move

- The forces are **balanced**
- **The resultant force** is zero
- **The net force** is zero
- **Sum** of forces is zero

$F_r = \sum F_i = 0$

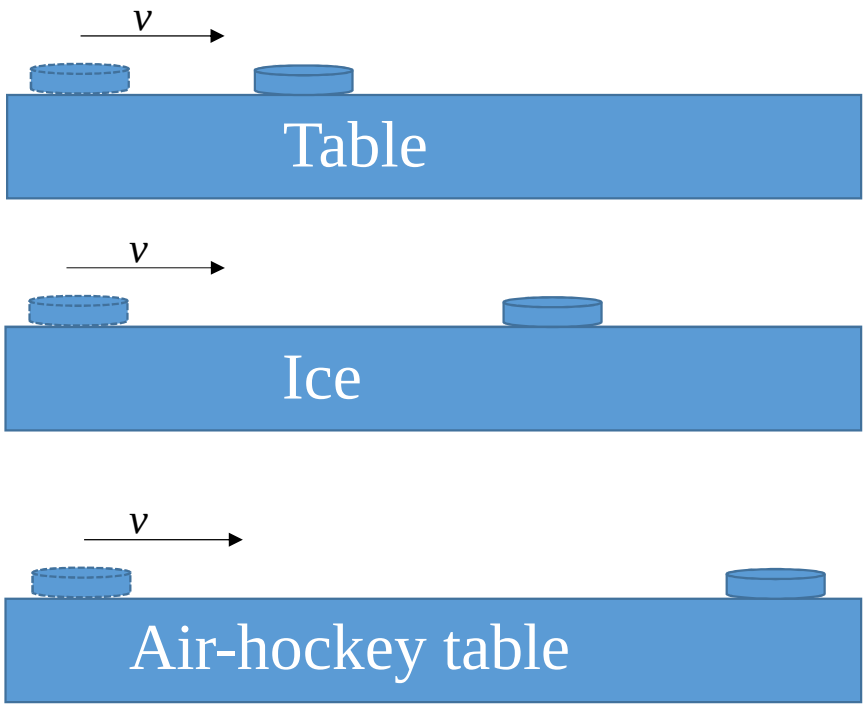


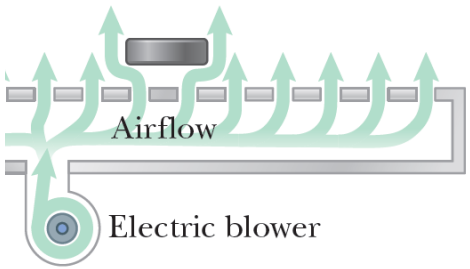
The book moves to the right

- The forces are **unbalanced**
- **The resultant force** is **not** zero
- **The net force** is **not** zero
- **Sum** of forces is **not** zero

$F_r = \sum F_i \neq 0$

Newton’s first law





Newton’s first law of motion.
A body will continue in a state of rest, or of constant speed along a straight line, unless compelled by an unbalanced force to change that state.

If $F_r = \sum F_i = 0$, object remains at rest or continues at constant velocity.

However, if $F_r = \sum F_i \neq 0$ velocity of an object will change. The amount of change depends on the mass and F_r.

Inertia
Is a tendency of an object to remain at rest or to continue in its uniform motion along the straight line.
Application of inertia: Differentiating between boiled egg and raw egg, without breaking them.

Newton’s second law

Newton’s first law refers to a situation where there is no net force. If a net force acts on an object, the object will change its state of motion according to Newton’s second law.

Newton’s second law of motion

If a net force acts on a body, the body will be accelerated; the magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the body, whilst the direction of the acceleration is in the direction of the net force.

Mathematically, Newton’s second law may be formulated as:

$$a \; \alpha \; \frac{F}{m}$$

or

$$F \; \alpha \; ma$$

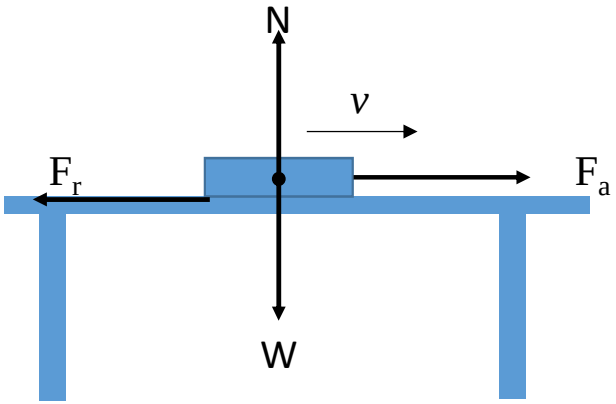
We remove the proportionality sign by introducing a constant equals to 1

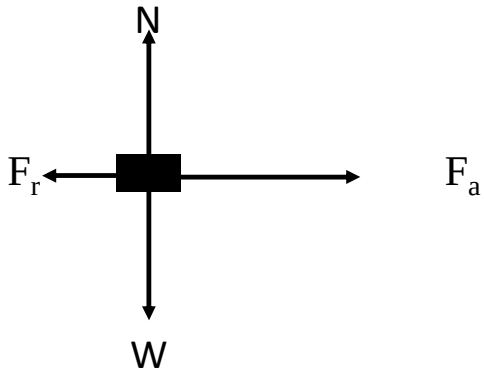
$$F = ma$$

In the SI, the unit of force is the newton (N). The newton is defined as the net force which will give a mass of 1 kilogram an acceleration of 1 ms^{-2} in the direction of the force.

Free-body diagram

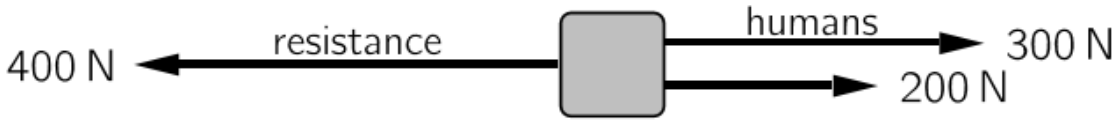
A free-body diagram is a diagram that represents an object and the forces acting on the object. The forces are represented by arrows (since force is a vector quantity) with length proportional to the magnitude of the force and the direction of the arrow indicating the direction of the force. A free-body diagrams should always be drawn when a problem involves Newton's second law.





Example 3.1: Free-body diagram

Suppose two people push a car along a horizontal road. One person applies a force of 300 N and the other a force of 200 N. The car has a mass of 1200 kg and the total force due to resistance is 400 N and acts in the opposite direction to the forces exerted by the people pushing. Draw a free-body diagram that shows the horizontal forces on the car and find the acceleration of the car.



Newton’s third law

Newton’s third law

If one body exerts a force on another body, the second body exerts a force equal in magnitude and opposite in direction on the first body.