**Chapter Two: Newton’s Laws of Motion**

**Newton’s laws of motion**: Three statements describing the relations between the forces acting on a body and the [motion](https://www.britannica.com/science/motion-mechanics) of the body, first formulated by English physicist and mathematician [Isaac Newton](https://www.britannica.com/biography/Isaac-Newton), which are the foundation of classical mechanics.

In his [*Principia*](https://www.britannica.com/topic/The-Mathematical-Principles-of-Natural-Philosophy), Newton reduced the basic principles of mechanics to three laws:

1. Every body continues in its state of rest or of [uniform motion](https://www.britannica.com/science/linear-motion) in a straight line, unless it is compelled to change that state by [forces](https://www.britannica.com/science/law-of-force) impressed upon it.
2. The change of motion of an object is proportional to the [force](https://www.britannica.com/science/force-physics) impressed and is made in the direction of the straight line in which the force is impressed.
3. To every [action](https://www.britannica.com/science/law-of-action-and-reaction) there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts.

**Newton’s first law: the law of inertia**

Newton’s first law states that if a body is at rest or moving at a constant speed in a straight line, it will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by a [force](https://www.britannica.com/science/force-physics). In fact, in classical Newtonian mechanics, there is no important distinction between rest and [uniform motion](https://www.britannica.com/science/linear-motion) in a straight line; they may be regarded as the same state of motion seen by different observers, one moving at the same velocity as the particle and the other moving at constant velocity with respect to the particle. This postulate is known as the law of [inertia](https://www.britannica.com/science/inertia).



[**basketball; Newton's laws of motion**](https://cdn.britannica.com/91/149891-050-8B81F749/basketball-player-jump-shot-arcing-path-Isaac.jpg)

When a basketball player shoots a jump shot, the ball always follows an arcing path. The ball follows this path because its motion obeys Isaac Newton's laws of motion.

*© Mark Herreid/Shutterstock.com*

The [law of inertia](https://www.britannica.com/science/law-of-inertia) was first formulated by [Galileo Galilei](https://www.britannica.com/biography/Galileo-Galilei) for horizontal motion on Earth and was later generalized by [René Descartes](https://www.britannica.com/biography/Rene-Descartes). Although the principle of inertia is the starting point and the fundamental assumption of classical mechanics, it is less than intuitively obvious to the untrained eye. In Aristotelian mechanics and in ordinary experience, objects that are not being pushed tend to come to rest. The law of inertia was deduced by Galileo from his experiments with balls rolling down inclined planes.

For Galileo, the principle of inertia was fundamental to his central scientific task: he had to explain how is it possible that if Earth is really spinning on its axis and orbiting the Sun, we do not sense that motion. The principle of inertia helps to provide the answer: since we are in motion together with Earth and our natural tendency is to retain that motion, Earth appears to us to be at rest. Thus, the principle of inertia, far from being a statement of the obvious, was once a central issue of scientific [contention](https://www.merriam-webster.com/dictionary/contention). By the time Newton had sorted out all the details, it was possible to accurately account for the small deviations from this picture caused by the fact that the motion of Earth’s surface is not uniform motion in a straight line (the effects of rotational motion are discussed below). In the Newtonian formulation, the common observation that bodies that are not pushed tend to come to rest is attributed to the fact that they have unbalanced forces acting on them, such as [friction](https://www.britannica.com/science/friction) and air resistance.

**Newton’s second law: *F* = *ma***

[](https://www.britannica.com/video/185499/lesson-forces-objects-same)

[Newton’s second law](https://www.britannica.com/science/law-of-force) is a quantitative description of the changes that a force can produce on the motion of a body. It states that the time rate of change of the [momentum](https://www.britannica.com/science/momentum) of a body is equal in both magnitude and direction to the force imposed on it. The momentum of a body is equal to the product of its mass and its velocity. Momentum, like [velocity](https://www.britannica.com/science/velocity), is a [vector](https://www.britannica.com/science/vector-physics) quantity, having both magnitude and direction. A force applied to a body can change the magnitude of the momentum or its direction or both. Newton’s second law is one of the most important in all of [physics](https://www.britannica.com/science/physics-science). For a body whose mass *m* is constant, it can be written in the form *F* = *ma*, where *F* (force) and *a* ([acceleration](https://www.britannica.com/science/acceleration)) are both vector quantities. If a body has a net force acting on it, it is accelerated in accordance with the equation. Conversely, if a body is not accelerated, there is no net force acting on it.

**Newton’s third law: The law of action and reaction**

[Newton’s third law](https://www.britannica.com/science/law-of-action-and-reaction) states that when two bodies interact, they apply forces to one another that are equal in magnitude and opposite in direction. The third law is also known as the law of action and reaction. This law is important in analyzing problems of [static equilibrium](https://www.britannica.com/science/equilibrium-physics), where all forces are balanced, but it also applies to bodies in uniform or accelerated motion. The forces it describes are real ones, not mere bookkeeping devices. For example, a book resting on a table applies a downward force equal to its weight on the table. According to the third law, the table applies an equal and opposite force to the book. This force occurs because the weight of the book causes the table to deform slightly so that it pushes back on the book like a coiled spring.

If a body has a net force acting on it, it undergoes accelerated motion in accordance with the second law. If there is no net force acting on a body, either because there are no forces at all or because all forces are precisely balanced by contrary forces, the body does not accelerate and may be said to be in [equilibrium](https://www.merriam-webster.com/dictionary/equilibrium). Conversely, a body that is observed not to be accelerated may be deduced to have no net force acting on it.

**Influence of Newton’s laws**

Newton’s laws first appeared in his masterpiece, *[Philosophiae Naturalis Principia Mathematica](https://www.britannica.com/topic/The-Mathematical-Principles-of-Natural-Philosophy)* (1687), commonly known as the *Principia*. In 1543 [Nicolaus Copernicus](https://www.britannica.com/biography/Nicolaus-Copernicus) suggested that the Sun, rather than Earth, might be at the centre of the [universe](https://www.britannica.com/science/universe). In the intervening years Galileo, [Johannes Kepler](https://www.britannica.com/biography/Johannes-Kepler), and Descartes laid the foundations of a new [science](https://www.britannica.com/science/science) that would both replace the Aristotelian worldview, inherited from the ancient Greeks, and explain the workings of a heliocentric universe. In the *Principia* Newton created that new science. He developed his three laws in order to explain why the orbits of the [planets](https://www.britannica.com/science/planet) are ellipses rather than circles, at which he succeeded, but it turned out that he explained much more. The series of events from Copernicus to Newton is known collectively as the [Scientific Revolution](https://www.britannica.com/science/Scientific-Revolution).

In the 20th century Newton’s laws were replaced by [quantum mechanics](https://www.britannica.com/science/quantum-mechanics-physics) and [relativity](https://www.britannica.com/science/relativity) as the most fundamental laws of physics. Nevertheless, Newton’s laws continue to give an accurate account of nature, except for very small bodies such as electrons or for bodies moving close to the [speed of light](https://www.britannica.com/science/speed-of-light). [Quantum](https://www.merriam-webster.com/dictionary/Quantum) mechanics and relativity reduce to Newton’s laws for larger bodies or for bodies moving more slowly.